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"Technological Innovation in the Design and Development of the Space Transportation System"

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MR. O'DONNELL: We don't have a firm schedule for all the subsequent briefings; however, the next one in this series will betwo weeks from today on Wednesday, Sept. 24, 1 p.m. Central time, 2 p.m. Eastern, at the Johnson Space Center. The topic of that discussion will be "Onboard Data Processing in the New Generation of Piloted Spacecraft." Subsequent briefings will be here at NASA Headquarters and at the three centers: Kennedy, Marshall and Johnson. Coming in today you should have received three handouts: a single-page status report on the Shuttle activities to date -- what the status of Columbia at the Cape. You should also have a set of printed copies of the vugraphs of which you will be seeing here today.

In the back of the auditorium there is a stack of brown envelopes; if you will self-address these and leave them with us we will make sure you receive a copy of the printed transcript of this briefing. We hope to have that in a few days.

This particular briefing is being piped in via a two-way hookup between here, Kennedy, Johnson, Marshall and the Dryden Center. Also, people at other locations are able to listen in and monitor only. However, we will be able to take questions from the four centers I mentioned. For kickoff of today's briefing we have NASA Administrator Dr. Robert A. Frosch, who will be followed by the Associate Administrator for Space Transportation Systems, John Yardley. Following these two presentations, we will open the floor to questions. Thank you. Dr. Frosch.

DR. FROSCH: Thank you all for coming. This briefing is intended to be generally background informative so that as the next series of events in the beginnings of the use of the Space Transportation System occur, you'll have had a chance to have as much background as possible. I suggested as I came in that as I looked around the room there were two or three people here at least who probably should have been asked to give the briefing since they write so authoritatively on the subject, and generally correctly. What I will try to do is give a general overview of the Space Transportation System -- how it's intended to operate and why we are building it; then John will go into considerably more detail, particularly about the Orbiter, the launch and the landing systems themselves. The emphasis is that in fact what we are building is a system intended to do a collection of things. Most of the attention has focused on particular parts of the system -- mostly on the Orbiter. But it is important to note that it is intended to operate as a coherent collection of objects in space and objects on the ground to do a set of tasks -- it is the total operation of the system which is the important thing that we have to focus on. The individual problems and the individual developments all have to be viewed in the context of the way in which they contribute to a total operation. So I will be at least mentioning a number of things that we consider part of the system although they have not always been treated tightly together as part of the system.

The first slide indicates some, but again not all, of the principal pieces that are involved -- the central crewed piece of the system, the Orbiter itself, together with the fuel tank for its main engines and the two solid rocket boosters that constitute the launch system, with the Shuttle ending up as the general purpose spacecraft and the reentry and landing vehicle and other pieces of the system that are intended for other purposes in the Shuttle; the system of things which is called Spacelab both manned and unmanned portions that fit into the bay of the Shuttle for experimental and developmental work; the inertial upper stage; and the solid spinning upper stages, A and D, which are the first set of upper stages intended for the boost of payloads from Orbiter orbits to other orbits including geostationary. And there will be later in the program other upper stages which will be used for these purposes. These constitute the principal pieces of space and launch hardware that go with this system.

The next pair of slides indicates some of the other portions of the system -- this indicates principally the major U.S. ground sites that are involved in the operation of the system: the two launch and landing operational sites, Kennedy Space Center, principally for eastward launches and to, come in at a later date, the Vandenburg Air Force Base which will be used principally for north-south launches and landings from those orbits; and the Dryden Flight Research Center co-located with Edwards Air Force Base in California which will be used as the initial landing base for the first flight or so and will continue to be an emergency landing base. Its advantage, of course, is Edwards' dry lakebed which provides a seven-mile landing runway for the first test flights. The Johnson Space Center is, of course, the responsible NASA center for the system development and will be the mission control center for NASA flights and initially the sight of mission control center for DOD flights. The Marshall Space Flight Center has the responsibility for the propulsion systems and will function during operations principally as backup in providing information and helping with any anomalies and problems with the propulsion systems. The White Sands Missile Range location is the ground station for the Tracking and Data Relay Satellite System (TDRSS) which will be an early payload put up by Shuttle and which will be used for the relay of data and communications from essentially all of our Shuttle-launched low Earth and high Earth payloads and for the Shuttle data itself gradually replacing the principal elements of the ground system, the current ground tracking and data system. So we consider TDRSS as part of the overall shift into the Space Transportation System and the White Sands Missile Range is thus a part of that. If I've got enough string I can come over here.

This next slide lists the principal elements some of which I've already indicated: the Shuttle system which is the Orbiter, the tank, the solid rocket booster, the engines which are in the Orbiter and the various ground and launch systems that go with it; the upper stages of which there are three currently prepared, (there will be future upper stages); Spacelab which has the pressurized module which may be crewed and pallet segments for carrying instruments that can be operated either from the cabin of the Orbiter or from the Spacelab crewed module; the Tracking and Data Relay System and finally, a number of augmentation systems that we have begun to develop to build around the initial capabilites of the system, both to bring it up to full capability and to go beyond that. Two of these involve providing additional electric power partly for a longer stay in space and partly for increased capability for experiments and the like. This is a particular version of an additional thrust module which would give us additional weight-carrying capability. Finally, we're looking at other systems involving large structural construction, and so on that would embroider around the basic capability to give us a more capable system. The next slide please.

This, of course, shows the 101, the Enterprise, on the mobile launch platform on the crawler in launch configuration approaching its position on the pad -- again the liquid oxygen-liquid hydrogen fuel tank, the solid rocket boosters, the Orbiter itself and the main engines. It is to be launched from the mobile launch platform as was Apollo. These are, in fact, the Apollo launch platforms extensively modified for this purpose.

The next slide gives a recap and a projection of the milestone schedule and history of the system. The authority to proceed started in 1972. We did the assembly and work on Orbiter 101 and the first captive flight and landing tests in '77 and '78, we have been assembling 102 and expect it to roll out in November of this year (1980) and expect first manned orbital flight by the end of March of next year with an initial operational capability after test flights at the end of '82, with the next Orbiters coming in '82, '83 and '84 with the first Vandenberg launch to come in '84. So that it will be the end of '84 or the beginning of '85 before we have all of the elements of the system -- four orbiters, both launch sites, etc. -- available for a full operating system. It will come into being as we can build it. That's the outline of the structure of the system. Now I'd like to go back and talk a little bit about the rationale for the system, the objectives and what it is we hope to do. Next slide please.

This has been the continuing statement of the objective, that is to provide a national system for space transportation which has features of economy and which, perhaps more importantly, has features of flexibility and capability that we do not now have available and have never had available. These objectives are to be achieved through reusability and reliability, through the fact that the system has some characteristics of versatility and flexibility, and a potential for being built on and built around to become more flexible and more capable to bring a new case of economic economy and efficiency into an operating launch system as opposed to a research and development system. This is a general recap of uses most of which I think are familiar. It is a delivery and placement system but importantly, for the first time, it will be a system capable of work on other systems in space, and of retrieval of systems from low Earth orbit from space, so that they can be brought back and serviced, experimented with and returned to space. It will, of course, serve as transit for laboratories and short-duration payloads and provide what we think is a safe and comfortable environment for those who go to work in space. The operations incorporate many things that we now do exclusively with free fliers unmanned, but the principal point is that we will be able to do things now with the intervention of people on the spot in an experimental way. We will be able to test and work with instruments without necessarily surrounding them with the design of a full spacecraft and we will be able to test out ideas, we hope, when we get operating on a relatively short-term, relatively economical basis before we go into unmanned operation. In addition, we can, of course, build up the whole set of capabilities of human operations in space about which we know relatively little but have lots of ideas.

Let me continue with this line of discussion with the next slide which essentially discusses the virtues of this kind of system. Of course, the first is a reduction in cost and I'll come back to a sample comment on that, the flexibility which I've mentioned, this can deal with heavier and larger payloads than we have been used to and, because of the flexibility of operation it gives us an opportunity to do something that we have not been able to do very well, if at all, before -- the capability to bring up several objects in sequence. Because we have the people there to assemble larger complexes in space than we have been able work with before as well as to construct things in space and those are important new capabilities that will require a good deal of experimentation before we really know how to use them.

This (slide) lists some of the items I have already mentioned and the fact that it is a crewed system, that it has accommodation for up to seven people means that a good deal of work can be done not only by very specially trained people, but that people with scientific and engineering specialties were needed for those specialties who may have minimal training in space operations, and finally a system with enough flexibility so that we can build around it and on it for future uses. Some of the capabilities include the baseline capability of seven days with four people and with the addition of fuel kits, up to 30 days with up to seven people and making the most of that involves some power extension capabilities that I mentioned earlier, mission stations for commander or pilot, mission specialist and up to four payload specialists. The commander and pilot are self explanatory, mission specialist are astronauts who have scientific, engineering and other technical specialties, will attend to the operation of the systems and the systems support, to payloads in a generic way and will also be themselves experimenting scientists and engineers. Payload specialists are the particular specialists in scientific and engineering fields who are needed because their specialties are likely to go beyond those the astronaut corps could conveniently have but would not be fully trained in all the capabilities of an astronaut but have enough training to safely go on a flight. The provisions are shirtsleeve normal atmosphere with controlled environment, good food arrangement, general hygiene facilities, relatively low acceleration for this purpose, the capability for spacesuit operations for payload support and for emergencies. So generally as close to an aircraft kind of environment as seems feasible at the current state of the technology.

The next slide gives a sample of which there should be a -- I think we're out of order, but maybe I've missed something. I thought there was a launch cost comparison coming up next. Number 9, there that's the one I was expecting. This is a sample of what the economics appears to be, we have put it in '78 dollars because we have the data in that way. It compares a particular case, a case of a Delta class payload -- that is the kind of payload that could be launched on a Delta expendable launch vehicle -- what it costs to buy and do the launch on that vehicle in '78 dollars, what our projected costs for that payload with Shuttle would be, and that has a dual capability, it depends some what on the way in which the payload can be arranged in the payload bay. We charge by the length of payload bay used or by the weight used for Delta class payloads, the governing factor is generally going be the length of payload bay, so it depends on whether the cargo can be put in a vertical position where it takes minimum length of payload bay or whether its got be inclined or layed down for some reason connected with the cargo, that varies the cost some what.

MR. HINES: (Bill Hines, Chicago Sun-Times) This is not the all-up cost of a Shuttle launch, but only the cost of launching the weight comparable ...

DR. FROSCH: That's right. That's right. Because normally, for those who may not have heard the question, the point was that this is not the cost of an all-up Shuttle launch -- this is what it would cost to launch a payload comparable to a Delta class payload. That's correct. And that is, in fact, how the pricing policy goes unless there is a special reason -- a partial payload would not have to pay for entire launch cost. So that that is an important point which has sometimes been left out of considera-tion in discussing the economics of the matter to the actual customer.

The next slide, if it's the right one, gives a perhaps somewhat over-graphic comment on the nature of the size of the payload bay which 15 feet in diameter by 60 feet long and can take 65,000 pounds into a 150-mile generally eastward trending orbit and the picture shows one of those double-length trailers that occasionally terrifies me on the highway. That's to fix a size which is comparable to the cargo size and weight.

The next slide -- now's where I'd like the mission profile one -- I think they're out of order; see if you've got the mission profile one for me. Okay, thank you. This is to show you what the total mission profile is intended to be and will serve me as an introduction to some of the things John Yardley will comment further about. The system is set up, and this is done terms of the Kennedy flow, and I will start with prelaunch, and there the orbiter will start from the Orbiter Processing Facility where it has been taken care of after its previous flight, and readied for a next flight. It will then have been moved into the Vehicle Assembly Building where it will have been put into a vertical position and mated with the fuel tank and with the solid rocket boosters on the mobile launch pad. The entire thing being then taken by the crawler out to the launch pad. The payloads may have been put into the cargo bay at any of these stages, but can be put into the cargo bay at the launch pad just prior to launch. The fueling of the cryogenic liquid fuels -- the liquid oxygen and liquid hydrogen -- are done at the launch pad. It is then launched with solid rocket boosters and liquid engines firing; the solid rocket boosters are staged and dropped after minutes when they are burned out. They splash down a couple of hundred miles down range, are picked up and returned to launch site because those cases and the hardware that goes with them are cleaned out, refilled with propellant and reused. At apogee but before orbit insertion the orbiter separates from the nearly empty fuel tank and the fuel tank which is the one complete throw-away element of hardware, is then spun falls back on a trajectory which whether the launch is east-west or north-south ends it up in the Indian Ocean. The orbital maneuvering system is then used for orbital insertion and the orbiter now operates as a spacecraft in low Earth orbit up to several hundred miles altitude, can change inclination and orbit within the limitations of its maneuvering fuel, and can do a whole series of launch retrieval and experimental operations. At the end of its time in orbit, it de-orbits with an orbital maneuvering system burn and then becomes successively a reentry vehicle going through the period of high frictional heating which is what principally slows it down from its orbital velocity and the period of communications blackout that goes with that; it emerges from that period as an extreme hypersonic glider under control, then becomes a supersonic glider and subsonic glider, finally coming into a terminal phase and landing on a standard runway. The one at Kennedy is about double width and long but it can land on a standard international major class runway as a rather fast glider of a couple hundred knots landing speed. To foreshadow one comment (one thing that John will deal with in somewhat greater depth), one of the major challenges in the system is to build an object which can be a launch vehicle, a crewed spacecraft, a reentry body and then a glider which will function under control hypersonically, supersonically and subsonically. I think it is worth the comment that no full-scale vehicle has been built and flown through that set of regimes.

This has been done with sub-scale models in various regimes, its been done in the wind tunnel, but no aircraft of this size --

it's about the size of a DC-9 -- have ever beer operated through that broad set of regimes.

Then we come, finally to the last two slides which simply will note for you that, as with any experimental system, we will be starting out with something less than our full capability. The first Orbiter is somewhat heavier than originally planned, and the tanks and solid rockets are somewhat heavier than they need to be with the engines at 100 percent power (what we call the fall power level as opposed to the rated power level) are slightly derated from what we expected originally and how that came to be 100 percent, I don't know. Someone here may know what the history of the 100 and 109 percent, it isn't clear to me why the 100 percent isn't 90, not 97 percent and the other was 100 percent, but at any rate it has come out that way. So we start out with 100 percent rated engines. The fact that there are two numbers here merely designates the first number is the number, the percent of power that we would proposed to be certified to operate the engine for throughout the launch; the second number is the percent of power that we would be certified to operate the engine for in case of an abort -- that is in case of some emergency that took special engine power. So the significance of these is that we will start out with the engines rated at 100 percent -- whether it's for standard launch or for an emergency. We will then move up to a period where the engines will be rated for 102 percent for flight, but certified to the point where, if we had a flight emergency that required an abort, we would then feel comfortable with going to 109 percent for that purpose and then to a period later where we'll get to confidence in the engines of 109 percent. The other steps in this increasing payload capability Eastern Test Range with the conditions noted on the chart and generally an easterly inclination, the second orbiter will be lighter than the first orbiter and therefore capable of a higher cargo payload. The external tank, we have plans to remove a considerable amount of weight without changing its capability, that is an increasing one. The first flights have ejection seats. That is a weight penalty which will go away when we are through with the early test flights. There are some improvements in the solid rocket motors and then the later orbiters will be sufficiently lighter so that we will get to the full capability.

And the last chart shows the same kind of stairstep buildup for Western Test Range generally north-south flights, same noted conditions and there the principal improvements will be the coming in of orbiters 103 and 104, which are lighter weight. There's also an indication there of the kind of performance that could be achieved there on the west coast of thrust augmentation, whether it's a liquid boost module or solid module or engine improvement would get us beyond the payload requirement. We cannot get the same improvements on the East Coast because we are much closer at the end of this set of improvements to the basic weight-carrying capability of the Orbiter itself. It's not just the total thrust we can provide that limits the total weight --

it is what the structural strength of the Orbiter is in carrying weight and that is in the end limited by the amount of weight that it might have to carry if we brought a payload back so that it is limited by the total capability of the Orbiter to land and take the landing stresses with a given weight and that's what puts the ultimate limit on weight carrying. Actually, it turns out, if one looks at the manifest that we have, we are in many more cases volume limited than weight limited. Most of the time it is fitting in the various packages that limits what you can do on a particular flight rather than total all-up weight. There are a few cases of DOD payloads and of NASA, particularly planetary exploration payloads, that really push the weight-carrying capability, but most of the time it is likely to be space rather than weight which is limiting.

Those are the principal introductory points that I wanted to make. In summary, it is a system rather than individual parts that ought to be concentrated on; the drive is for flexibility and a system that we can build upon, as well as for economic use in doing the things we can already do and it is, as I think I've indicated, a rather complex system and we hope to give you a clearer idea of what the various parts, complexities and difficulties are in the course of this and further briefings. With that I will turn this over to John Yardley to go into more detail.

MR. YARDLEY: I hope everybody understood Dr. Frosch when he said crewed; he meant c-r-e-w-e-d -- I don't like him calling my Shuttle crude, c-r-u-d-e. (Laughter) First chart please. In the length of time we have I certainly can't go into a lot of detail on the technical.... technological innovations of the Shuttle, but I want to show you some illustrations and you will be getting more detail in subsequent briefings at the centers. First of all, the introduction to the Shuttle vehicle, Dr. Frosch has done a pretty good job of mentioning what the major elements are; I though we ought to call out some of the major contractors: Rocketdyne on the engine, Rockwell on the orbiter, Martin on the tank, and Thiokol on the booster, or actually motors. The chart on the right shows a picture of Orbiter 102 in the Orbiter Processing Facility at Kennedy, shortly after its arrival, which was over a year ago, its -- we're using this picture because it's one of the pictures we've got without all the workstands around it, so you can see something. Next chart please.

Leading off with the structure of the orbiter just to give you a feel for some of the things that are different about this machine and that were felt necessary to do this mission, we see things like titanium/boron, composite thrust structures which are light but are pushing the state of the art. In general, though the structure was chosen for its simplicity; it's aluminum because that's light. We decided early on that we had to insulate the structure whether it was alumnium or titanium or steel because the temperatures we were going to see were way too high. So it turns out that under those conditions aluminum, its easy to work and cheap, was the most economical also weight wise. We used a lot of composites in other places, which I'll touch on in some of the more detailed charts. Next chart please.

Payload bay doors are very large as you can see -- they're covering up those twin trailers of Dr. Frosch's. These are very light also. These doors, of course, have to open and close reliably, but more than that they carry the torque of the fuselage structure. They are designed so they will not pick up the bending, but without the doors carrying the torque we have a very flimsy fuselage. These doors are graphite epoxy and, I think, they're the largest pieces of structure ever built out of graphite epoxy. So they save us about 900 pounds, it would have been about 3,000 pounds, without this, with the aluminum design we had originally. The doors are split into five sections each, and have slip joints between them so that they can't carry either the bending loads or build up thermal stresses in themselves. Next charts please. (Inaudible) Oh, here's a picture of the door, yeah. One section of the payload bay door in the test picture. Next chart please.

Now I'm sure most of you have heard of the thermal protection system. It is, I'd have to say, all new in terms of having ever been used in a flight article, either this particular one or this type. In previous programs where we had reentry requirements we used either heat sinks or ablators. Nobody had really invented a type of insulation that could do the job. Some people question whether we have invented it yet, too, because we had a lot of problems with it. The need for this though is evident, obvious because we want to reuse and you can't reuse an ablator. An ablator burns up as it protects you, so you have to replace it. Well this is a large vehicle and replacing its heat protection every flight would have been unworkable with respect to an operational vehicle. So we came up with various ways of solving this problem which are new and which we've been in eight years of development and which we think now we've got well under control. On the hottest parts, that is the wing leading edge and the nose cap, we use what we call carbon carbon. It's pyrolized carbon and the big problem with that was to get it so it would not oxidize too rapidly. Vought has developed that for us. It's been fully qualified; we've had very little problems with it. Right now we think we've got somewhere between a 40 and 50 flight capability on those parts. We were shooting for a 100, but it looks like that's not quite at the state of the art yet. The ones we've been having more trouble with are the tiles, which are manufactured by Lockheed -- and I don't want to infer that Lockheed is a problem here -- because it's really been the tile assembly and installation that's been our primary problem in the last year or two. The tiles have been okay. These are very light -- nine pounds per cubic foot. Your average tile weighs less than half a pound. They are very good insulators and we have developed coatings that will let them withstand the surface temperature of 2,600 degrees, and on the heavier tiles these are

2,800, and keep the structure, the alumnimum structure underneath, below 350 degrees. So on the thermal side they're very good. They do have some undesirable characteristics. They are ceramic and very brittle and are not very strong and the development of an installation system -- could I have the next slide please -- to solve that problem has been quite laborious.

This shows an illustration of how we attach a tile. We actually have to treat the inner surface of the tile with a process that makes it much stronger at the inner surface which we call densification. We have different coats of RTV; we have a felt underneath there called Nomex, and different adhesives and primers under that. Now all of these steps have to be very carefully controlled because the strength of the tile is very important to us. If a tile comes loose it could be a bad day. So we're taking extreme precautions to make sure no tiles come loose. We're proof-testing every tile, every joint to loads which are quite conservative to make sure that these tiles are adequate. We feel that we're over the hill on this and we expect to have all the tiles on by mid-November.

Now in addition to the -- could I have the chart on the right, the previous one back for a minute please. In addition to the black high-temperature tiles, we use the same tiles only with a white coating on them, these are generally thinner and we use those in lower temperature regions. Generally you'll see them where it says LRSI, along the sides and on the sides of the fin, places that don't get over 1,200 degrees. The reason we make them white is that's a better thermal characteristic in orbit. The black is necessary for emittance during entry where the temperatures are quite high. But these tiles still have the same problems as the black tiles in terms of their limited strength, their ceramic brittle character and they have to be treated essentially the same way. The difference is, one of these tiles coming off is not felt to be a real catostrophic type of occurrence if you have some repairs to make. Then in lower temperature regions, below 800, we find that felt that we put underneath these other tiles is adequate in itself with the proper white RTV coating on it, to withstand the, to insulate the structure and keep it below 300 degrees. And that's what you see on the top of the payload bay door and on the side of the OMS pod on the rear side of the orbiter. Next slides please.

Okay, going on into another of our subsystems, the orbital maneuvering system, basically this is a reusable propulsion system in itself that is good for a 100-mission life, reusable. There are a few innovative things in this and I'd like to call to your attention. In the engine they've developed a new platelet concept of building the injector which gives us high performance and ease of fabrication and good tolerance control. You might say its analogous to printed circuits and ejectors. They developed acoustic cavities to control the combustion stability and were able to get by without baffles. And they're regeneratively cooling the thrust chamber which is not anything real new. Now on the OMS structure, the pod itself the structure is also graphite epoxy and that's saved about 500 pounds. One new innovation for NASA is the use of acquisition screens in our propellant tanks on orbit. Previously, we've always used bladders for the zero-G operations of our propulsion systems. Bladders have a lot of drawbacks. We've never really gotten bladders that could stand more than a few cycles, so it would have been a maintenance problem. So this is pushing the state of the art; all of our tanks have these kinds of screens. They are screens that are fine mesh screens that when they're wet they will let fluid pass through them but not let the pressure and gas pass through them. And they essentially collect and feed zero-G through surface tension phenomena, collect and feed the feed line out of the tank. They're arrange in various fashions depending on the tank geometry. Some of the vital statistics here, we do have a 6,000-pound thrust on the OMS engine. It normally will be, well its felt to be, the capability is normally about 1,000 feet per second. We had in the program, but not completed yet, what we call payload bay kits which are additional OMS tankage that we can put in the payload bay and feed the system so that this can go as high as 2,500 feet per second for a lot of orbital maneuvering capability if you so desire. Our first planned usage of that capability will be to boost the Space Telescope to its operating orbit. Next chart please.

Another item that's new that we have to depend on, the life and death dependency that has never really been used in that fashion before, and that is the hydrazine auxiliary power unit. We power our control surfaces, our engines gimballing, engine valves, the landing gear and so forth, with hydraulic power. Now airplanes, of course, have used hydraulic power for years and that's pretty well-developed technology. They drive them from engine-driven pumps and unfortunately, during our entry, which is a major requirement, we don't have any engines going. So we have to put engines in which are these auxiliary power units to drive hydraulic pumps. This has been quite a development. We have now qualified our APUs for about 20 hours of operation. That will get you maybe 15 to 20 flights, but we really are hoping to do better. It's fairly efficient in terms of weight -- it develops about 150 horsepower for a 92-pound weight. It's cooled by the gas generator exhaust, the gas generator is cooled by the turbine exhaust, which is an unusual way to do it. Zero-G gravity, zero-G loop system was necessary to develop because obviously it works in zero-G, for the early part of entry at least.
You can see we carry three of them, we have three hydraulic systems, the unit is shown here close-up and we have three on the aft side of the payload bay rear bulkhead. Next slide please.

The main propulsion system is another one that has represented quite a challenge for a number of reasons. This slide shows it sort of as a lump in the aft fuselage. The whole orbiter aft fuselage is almost dedicated to the plumbing, valving and so on. The three major liquid engines, and this little schematic shows that these three engines through the plumbing in the aft fuselage of the orbiter are fed by the external tank. We had a lot of different problems in this system -- next slide please -- that had to be solved. Some of the new things, the engine itself was by far the largest technical challenge in the propulsion system and ranks right up there with the TPS in terms of difficulty and advancement in the state of the art. Long life and reusability is a requirement that no liquid rocket engine has ever had to have before. If you were sure they'd last for the one flight that was good enough. We have set us a target of 55 flights for the basic engine. Throttling is another one that has not been done, not been common at least, in major rocket engines. We also need -- well let me answer Dr. Frosch's question about how did it get to be 109 percent. Originally this engine was thought to be developed for a 100 percent normal operation and 109 percent abort. And the first year or so of engine development went that way and they found out that as they were doing that, well, they were really designing everything for 109 anyhow. About that time the program weight was not quite like they'd like it, so they decided they would just make it good for the full power level for the full time. So that's how it got that way and it's been that way for about seven or eight years. The significance only has, the difference between these just has significance in the fact that those were a couple of levels. You could have made this 110 or so forth. We have to throttle it down to about 65 percent in order to keep our mission profiles, Gs and dynamic pressures under control -- that's a requirement that has not been usual for liquid rocket engines.

Now here's one that really was a driver, the minimum envelope requirement. You can see that the orbiter with these three engines on the back end is not exactly the most streamlined body you've ever seen. In other words, it's got a big, blunt back end. And that means that its lift-drag ratio is low, it lands hot, and so on. Now if we let the normal engine technology, if we use that, that rear end would be quite a bit larger and actually getting a flyable machine would have been marginal. So that drove us to high combustion chamber pressures, three to four times as high as pressures in this engine, as in any previous rocket engine. Some of the vital statistics on the engine here, I think you've seen most of these before, 3,000 psi chamber pressure, and that's at the 100 percent. It's about 3,250 or so at the 109. It has the highest specific impulse of any engine built to date -- the best we did before was in the 430s, this is 455 -- and that's very important in a machine that has only one single liquid stage. A lot of people refer to the Shuttle as a stage and a half. Now when you have your main liquid stage go all the way from launch to orbit, it's very important to have a high specific impulse. The life has been and will probably continue to be a problem. We have developed the 100 percent engine up to a point where we think its life is between 15 and 20 thousand seconds before it will start getting significant fatigue problems. We have to go further if we want to get 40 thousand seconds if we can. Next slide please.

Now one of the things that we did on this engine, both to save weight and to get the high specific impulse, we used what we call a stage combustion or a closed cycle operation. And let me just say in very simple terms what that means. We have a hydrogen pump that takes the hydrogen from the tank and pressurizes it to feed into the combustion chamber and we have an oxygen pump that does that. Now previously most rocket engines had a, had another combustion chamber which was burning some of the propellants to drive turbines to feed the combustion chamber and they dumped exhaust overboard. The exhaust from that turbine. Here we actually put our combustion chambers as part of the engine. We burn a pre-burner here on the hydrogen pump and a pre-burner on the oxygen pump which are controlled separately to vary mixture ratio and thrust. We then take the exhaust gases from this pre-burner and feed them into the main burner and we burn it all. Everything that comes out of the engine comes out as thrust and that makes a significant improvement in specific impulse; it also makes the engine a compact, light system. You don't have long plumbing runs and so on. We operate internally in this engine up to 7,800 pounds per square inch, and that's a pretty high pressure. The temperatures generally are another source of problem -- we're for operating at higher temperatures than most people did in the past, considerably higher than say airplane gas turbines. Here's your turbine section, it's driven by the fire in the combustion chamber here. We run in this turbine about 17, 16 or 17 hundred degrees Rankine and this turbine, we're about 1,500 degrees Rankine. Now the materials to take that are in good strength, are not too plentiful. We've had problems with our turbine blades. Because they are such a tough environment to see, our turbine blade life is around 5,000 seconds but we inspect for each run, each flight and replace the blades at any sign of a crack. So that problem's under control; it's one we'd like to improve. Next chart please.

The main combustion chamber took some technological innovation too. We have a higher heat flux by a factor of 5 to 10 than most low-pressure engines and this required a unique cooling system which we evolved by getting a good conductivity by electroplating. The last operation made up the tubes which are actually machined in the wall of the chamber. The chamber is not high Z and then we electroplate to close that out and that gives good cooling and good strength to it. And we've had quite a good deal of success with that. Next slide please.

The high chamber pressure I mentioned earlier that we operate at three to four times that of any other engine and that does provide for good ISP too, and does, of course, require high-temperature materials -- we have pressures as high as 7,500. This is kind of interesting, the horsepower we developed in developing one of these pumps -- that's fuel turbopump which is the highest powered one -- is about 62,000 horsepower and weighs 700 pounds and that's a density of 88 horsepower per pound which is pretty fantastic. Gene Covert, who's a professor at MIT, has been working with us on this engine for a few years. He likes to call this three 707s in a garbage can or something like that because it is about the size of a garbage can. As you can see, this pump is very dense -- it's got three stages of the pump and two turbine stages. This is where your combustor is on a preburner comes through the turbine nozzles, drives the turbine and exhausts out of the turbine and into the main combustion chamber. The high speed pumps have been a problem in development of both the hydrogen pump and the LOX pump. We have configurations now with all of our fixes that look like they're good and durable and certifiable for 100 percent. We have run our present engine at 109 percent about 1,000 seconds. We have one engine at that and we found no problem, but we know the fatigue life of the parts is going to be a problem sooner or later at those higher stresses. Next chart please.

Finally, on the engine, this is the first rocket engine that has even been computer controlled. People were somewhat dubious about this in the past, you know when we started, but this has really turned out to be a real plus. It gives us flexibility in changing mixture control, changing start sequences and changing stop sequences, and it's really been a valuable development tool much less it's going to pay off for us in the operations. There's nothing fundamentally new or technologically innovative in terms of the hardware, but the use of the hardware in a closed-loop engine cycle like this is a new phenomena. Next slide please.

Avionics -- we could spend hours on this -- but let me just pause a minute on it. You're going to get a fairly good dose of this down at Johnson in two weeks so I won't dwell on it. Basically we started out with an all fly-by-wire digital system, which at the time the cornerstone was laid back in early '72, this was the only vehicle committed to that. Now since that time, airplanes have begun picking it up but they don't depend on it as much as we do. We don't have any control cables or control rods, drive valves, we're entirely dependent on electronics. We have four what you might call separate electronic systems driven by four computers and most of the end effectors and the data sources, the sensors, are also quad-redundant. This presented us with quite a capability and makes a very safe system but it does make it very complex in terms of developing redundancy management techniques. So that has been a problem although our software has come along quite well. We're fairly comfortable that we've found the bugs in the software and the machine. This just shows some of the avionics systems, but when you get right down to it, you can't really even lower the landing gear without the computer. Next slide please.

The External Tank doesn't have any real advanced technology in it. I think it's the biggest single-stage fuel tank ever built, so in that sense it's got some new problems. It's not the biggest diameter ever built. The Saturn first and second stages were a few feet bigger in diameter. I didn't want to leave it out because it is a difficult task to design and develop a light-weight, cheap, external tank. It's not as cheap as we would like it to be. We have to put a lot more hand insulation work on it than we intended and we're working ways and schemes of eliminating that in the future. Next slide please.

The solid rocket booster is also unusual in some senses. Its primary requirement that's different is reusability. We want to reuse all the hardware quite a bit, somewhere between 20 and 40 times for most of the hardware. Parachutes, we'll probably get about 10 uses out of that. These are the largest operational parachutes ever used. Plopping this big thing down into the water and not bending it, and getting it out and reusing the equipment represents quite a challenge. It was designed for all that. We have yet to see how successful we're going to be. We plan to take the first two boosters that come back apart and make sure that water didn't get in where it shouldn't and things like this, so that in future reuses we can just turn around without disassembling the whole thing. This as a rocket, of course, has a requirement that is more stringent than any other solid motor and that is, it's got to work 100 percent of the time. There is no forgiving failure mode in a solid motor that has to work all the time. If its case burns through you lose control and so forth. So it's been designed to have much bigger safety factors and insulation thicknesses, nozzle walls, that sort of thing, than previous solid rockets. And in our test program we fired four development and three qualification motors, all seven 100 percent successful. Next slide please.

Finally, the launch processing, checkout and control system that we have operating at the Cape is another innovation. It's the next generation of automated checkout equipment. It's controls just about everything at the Cape including the valve positions inside the orbiter and inside the tank farms. It takes all the data , crunches it up and displays it on colored tubes to the operators and so on. There are a couple of advances in the state-of-the-art made here even though the actual hardware is shelf-type equipment: the networking of the many computers and real time command and control by using the common data source is new and this is a large system. And of course utilization of the automated checkout and process control language to program the system is another first. We don't have programmers programming the computers; we're actually using the language called "goal", where the engineers can more or less write out their instructions such as the closed-valve 15 and that's the programming. On the right you see a picture of one of firing rooms with the LPS equipment. It turns out that these are the same consoles that were used in the firing rooms for Apollo except they turned them upside down and rebuilt them for LPS.

That's all I have this morning so I guess I'll turn it back to Bill.

MR. O'DONNELL: Okay, while they're getting the stage ready here for the Q and A, I'd like to remind you again to please fill out or self-address an envelope at the back so we can get the transcripts to you. This also gives us a list of names so we can keep in touch with the people who are at these various briefings. That goes also for people out at the centers -- if they will let us know if they want a transcript, we'll get it to them. Now for the questions, if you would please wait for the microphone before you start asking your question and for the purposes of the transcript we'd appreciate it if you would identify yourselves. Okay. Craig.

MR. COVAULT: Craig Covault, Aviation Week. John, could you give a short status vis-a-vis the status of a about month ago and a second more detailed response to the situation in the OMS pods now vis-a-vis status and SSME from the standpoint of any open items on problems?

MR. YARDLEY: Basically, status of the overall work involved in getting to STS-1, we set the schedule about five or six weeks ago, and while new things have come up, they're all things that are within the envelope of the schedule we've got and all the milestones we had set for us, for ourselves, in that six weeks have been done. No problem has come up that we would be concerned about bumping that schedule. As far as the OMS is concerned, the OMS pods, we actually got them off the vehicle over a week early. They are in work now in the hypergolic facility. All the parts necessary are there and there doesn't seem to be any problem with respect to getting it fixed and back on the bird on schedule. Now there's always a threat because the fixes we're putting in we're also putting into a test article at Johnson, which will have to be run through the vibro-acoustic again. So if that shows some of our fixes are inadequate, then that could be a schedule problem. On the engine, we've begun engine testing again. We're testing on all three stands again. We completed the third certification cycle on 0009 last week. It is currently being fitted with the changes for the burn through we had and will be ready to run tomorrow (Sept. 11) on the first run of the fourth cert cycle which will be run at 102 percent instead of 100 percent; 2008, which is our first full-power level, 109-percent engine designed with all the newer stuff in it, we have on a test stand at NSTL and we made its first run yesterday, which is normally a one-and-a-half-second run to check out how goes it and it'll have a second acceptance run tomorrow or the next day. Triple-07 out at Santa Susana is the engine that we're doing the development test work on to make sure that our fixes will work. And we ran a very significant test yesterday, last night late. We put the fixes in for the burn through and then we purposely damaged two of the injector posts in a way that would cause a burn through and we actually cut a hole through one, through the liner of one of these posts. Our objective was to make sure that we could survive another failure like we had in 6 and we have to create the failure because it only happens about every 300 runs. Results I have at this instant of time, all the temperatures inside the engine and the case all remained normal. So it looks like our fix was working -- that is if our damaging the injector post actually caused the same problem. We have to look inside to make sure that the problem was really there. So that's a quick answer.

MR. COVAULT: What new stuff in the last month was there?

MR. YARDLEY: Well, the only new stuff, Craig, were the guys reappraising other parts of the vehicle for liftoff loads. Now the OMS pod fixes were as a result of the vibro-acoustic tests which showed that the analysis of getting from the outside environment to the inside accelerations was inherent. And they have used about 12 modes for these analyses and they went and used 50 modes and they came up with a pretty good correlation. So they're going back and look at other pieces. And right now, there's a possibility, they're concerned let's say, about a couple of fittings in the forward RCS radiator fitting, those are the only two I can recall right now. But when we first hit something like that we start working a fix and we get the parts ready to go in before we're sure its a problem. So those problems are such that they won't bump the schedule either.

MR. O'DONNELL: Albert.

MR. SEHLSTEDT: Albert Sehlstedt, Baltimore Sun. Mr. Yardley, you mentioned two types of tiles. I wondered if you could say what the thickness is of each type of tile and also approximate how much of the exterior is covered with tile?

MR. YARDLEY: Okay, there's really basically white tile and there's black tile and the white tile, they're both the same material with different coatings. The white tiles range up to about one inch from say a half inch to one inch. The black tiles generally are above one inch and go up as high as three and a half inches thick. Now there's a special kind of black tile that is a heavier material, it's a denser material of the same base material. It's 22 pounds per cubic foot instead of 9. We use that in areas where it needs high strength or it's got a little higher temperature and I don't have a precise figure, but I think about 75 percent of the Orbiter's got tile on it.

MR. O'DONNELL: Okay, Dave.

MR. DOOLING: Dave Dooling, Huntsville Times. John, could you go over briefly again the problems of the software. From some of things I've heard, it was really a tough nut to crack for a few months there, the flight software.

MR. YARDLEY: The biggest concern with the software, I'd say in the spring, was in the descent flight control part of it. We were testing the basic software and we were able to find some conditions that you could get out of control. They were extreme worst on worst cases with broad tolerances away from our wind tunnel tests and things like this. So the guys went back and invented some new filters and put that in and that software has been working very well and we don't think that's a problem anymore.

DR. FROSCH: I think the comment should be made that that's not really a software problem in the sense that, can you program together to do the right algorhythm. The problem was whether in fact we had the right flight control equations, whether the behavior of the vehicle as modeled was what the behavior of the real vehicle would be and there were some places where the worry was that we might be too close to the stability boundaries and one had to correct the equations so they'd be a little more modern.

MR. YARDLEY: I'd like to make another comment relative to that. The software will be a long pole in the tent no matter when you fly because, not because the software's later in but because it's so much more flexible to make changes in the software than it is in the hardware. We've got a couple of problems we're solving right now and between hardware and software, so they have to go back and redo the software. So it's always been that way, and it will always continue to be that way. It's not that there's any basic problem with the software, it's just a tool to solve other problems.

MR. SCHEFTER: Jim Schefter, Popular Science. John, what are the key things that you're going to be looking at over the next couple of months that could impact the launch schedule in March?

MR. YARDLEY: Well, of course, the engine testing. If two months from now we find an engine problem that takes some time to solve and have to start another certification cycle, you see right now our cert cycle will be complete by the end of December. That still gives us a three-month cushion. If I ran into an engine that had to repeat a cert cycle over a three-month period, I could be in trouble. There are certain tile certification qualification tests planned for the December-January time period, I have a lot of confidence we'll pass those tests, but if we had a problem there, that could bump the schedule. The OMS pod, for example -- if these later tests show that some of our fixes are inadequate, that could be a problem.

MR. O'DONNELL: Back there, Bob Asman.

MR. ASMAN: Bob Asman, with NBC. Dr. Frosch, could you discuss the integration of the prime crew with this early flight testing or the early testing? In other words, how much has the prime crew been involved in some of the software development?

DR. FROSCH: Well, I guess Bob Crippen is regarded as the software expert of the astronaut corps and one of the software experts on the whole subject. He has been involved in the logic and some of the software development and is, I think it's fair to say, used as an engineering consultant in the whole software problem. Of the two prime crew members, John Young and Bob Crippen, he's the expert on the software. It's generally the practice that members of the astronaut corps work as engineering or technical specialists during the development and that's true of essentially all the members of the corps. It is the case that Bob is the one who specialized in the system software.

MR. O'DONNELL: Down here, Lazlo.

MR. DOSA: Dosa, Voice of America. Do you have any tentative timeline for the first flight?

MR. YARDLEY: Oh yes, we have fairly detailed timelines which we can get for you. Basically, as I recall, it's a 54-hour flight and it's basically an engineering test flight where we're going to test out the systems and we'll be going through a re-entry rehearsal a day ahead of time and be prepared, if something's wrong to come in at that time and things like this. There's no scientific activity that I'm aware of.

MR. O'DONNELL: Al Rossiter.

MR. ROSSITER: Al Rossiter, UPI here. John, what is the plan now for ejection seat removal. I noticed in Dr. Frosch's chart that it was scheduled for '83 and I thought the original plan was to remove the seats after the first four flights.

MR. YARDLEY: Howard, right now, our plans are being made such that we can remove them any time after the fourth flight up to the ninth. It just is a flexibility to see where we are. In other words we want to be able to have all the hardware and everything, but depending on what's going on, you know that's a fairly, let's say an extra few months layout, we may elect to not do that since we don't have any more than two-man flights up until the first Spacelab, and make some of those flights to make Stan Weiss' customers satisfied.

DR. FROSCH: It's not really a matter of the ejection seat use but simply not necessarily wanting to interrupt the flight schedule in order to take out those seats before we actually have to because we need the weight-carrying capacity.

Q: You would expand the crew size sooner?

MR. YARDLEY: We haven't really crossed that bridge but that's been our basic thinking. You wouldn't want to fly -- it would be poor taste to fly two in ejection seats and two not. (Laughter). There's another practical consideration, that is, you don't have room in that upper deck with those big seat structures to really operate effectively with more than two people.

MR. O'DONNELL: Seth Payne, back here.

MR. PAYNE: Seth Payne, Business Week. On one of the slides that you had, Dr. Yardley, you showed the tiles, and there was a little thing that said thinner on the lee side. What would be the lee side of a reentry vehicle?

MR. YARDLEY: That's a, I guess that's a term borrowed from the sailors.....

MR. PAYNE: It'd have to be down wind.....

MR. YARDLEY: One is windward and one is leeward....just like sailing....

MR. PAYNE: You're coming in at the....

MR. YARDLEY: I'm coming in at a 40-degree angle of attack so the wind is on the bottom and the top is the lee.

MR. PAYNE: And even at that speed you do have an identifiable lee side.

MR. YARDLEY: Yes sir.

MR. PAYNE: So does that mean also that you must, you have a kind of a rigid reentry pattern?

MR. YARDLEY: Well, it depends on how you define it. It's rigid in the sense that we want the angle of attacks maintained. It's flexible in the sense we have plenty of control to make sure we come down at the right spot and, of course, in future flights, not on STS-1, we'll actually have control to go crossrange up to 1,100 miles.

MR. PAYNE: Quickly, could you tell us what progress you're making in finding a new type of thermal protection system?

MR. YARDLEY: Well, we have identified some improved tile materials that we're in development on now. For example, I mention the LI 2200 material, that's heavy. We've got another material that's equally as strong and about half as heavy, that we hope to qualify and begin using. We have not really found a good substitute yet for the lighter weight tiles. We still have some development going on that. Basically, these developments are in the direction of making the tile a lot stronger without adding any weight and without hurting its thermal performance. So we're moving along that path. We're also studying other tile systems that would be farther downstream. There is some concern, that's been expressed by outside people that have looked at the system, that maybe the type of felt we have under the tile may get loose and sloppy after 30 to 40 flights, and we'd have to replace them. We'd like to be in a position, if that happens, to replace it with something better. So we're working on a large variety of fronts.

MR. PAYNE: Are you working on an improved tile? In other words are you sticking with tile as the basic....

MR. YARDLEY: No, we had a study going down at Langley on metallics, metallic heat protection, more extensive use of carbon carbon and so on.

MR. O'DONNELL: Howard Benedict, back here.

MR. BENEDICT: Howard Benedict, AP. If everything goes according to schedule, what are your dates now for, say rollout, the movement to the pad, the FRF and for the actual launch time?

DR. FROSCH: Okay, rollout is before the 23rd of November. Launch is before the end of March and I guess at the moment there is talk of a possible date at the middle of March, FRF I don't...

MR. YARDLEY: FRF is currently shown as 7 February.

MR. O'DONNELL: Everly.

MS. DRISCOLL: Everly Driscoll, ICA. John, I got lost somewhere in your technical jargon, after the pre-burner.

MR. YARDLEY: After the pre-burner?

MS. DRISCOLL: After the pre-burner. I guess, an answer, a simple answer to the question would be are we going to have a more detailed less technical explanation of how the engine works and all this at some date down the line?

MR. YARDLEY: Down at Marshall, I would expect .... It won't be less detailed, it'll be more detailed.

MS. DRISCOLL: I'm sorry, I meant more detailed, less technical, in terms of jargon...

DR. FROSCH: We may have to strain it a bit.

MR. YARDLEY: I don't think we can get both.

MS. DRISCOLL: That's okay. So then, the short answer -- how would you simply compare this engine to say, a jet engine? Besides the fact that you use the exhaust, is that correct?

MR. YARDLEY: Well, a jet engine, it's harder to compare. They're both turbines, they both burn, but one has a compressor for fusing air. We have to pump oxygen and the jets operate at much lower pressures and temperatures and they're much bigger. You really have to compare it with rocket engines, previous rocket engines.

MR. O'DONNELL: Okay, I'll take one more question here then we'll go to the centers. Don?

MR. KIRKMAN: (Don Kirkman, Scripps-Howard) John, going back to the TPS, there was some talk earlier that you might have a new kind of TPS on the fourth orbiter -- it was a possibility. My question is, are you committed to the current system you've got for all the four spacecraft you're building now, or what?

MR. YARDLEY: No, you're not committed. Right now we're working on improvements and when we get the improvements and we're confident of them, we'll program it in wherever we happen to be. Right now on our second orbital orbiter, 099, we're going to start putting TPS on this October and we're not ready to do anything new yet on that. We have hopes that we'll have this LI 2200 ready to catch about the last half of those tiles and save ourselves about 5 or 6 hundred pounds. But we're not commited and we'll commit as time goes on. If we get something in time, we'll do it.

MR. O'DONNELL: Okay, do we have any questions at Kennedy?

MR. HARRIS: (Hugh Haris, KSC) Yes, this is Kennedy, and we have a number of questions. The first is from Dave Bailey of the Today Newspaper who asks: "The recent magazine articles reported that NASA said that the Shuttle turnaround, instead of taking two weeks as originally predicted, will take more than 200 days. What is NASA's current prediction of the turnaround time of the operational phase?"

DR. FROSCH: It depends on when. Clearly we're going to start out with much less turnaround capability than we will eventually learn to have and the turnaround time that's scheduled between the first flight and the second flight is like five or six months. We're aiming at getting down to a couple of weeks. I don't think anybody has an expectation that we will be able to do that in less than several years. It's a learning process. I don't know where the 200 days came from. That's a new number to me even in everybody's most pessimistic imagination.

MR. YARDLEY: I think I might be able to shed some light on that. There is an active analytical effort going on all the time that started out as 160-hour turnaround. It is now at 280 hours, just from the evolution of the thing. It appears this author got the 280 hours confused with 280 days. Actually the manifesting that's being done out three or four years is assuming five weeks, which is a lot more hours than either 280 or....

MR. O'DONNELL: Okay Cape, got some more?

MR. SHOTKNECHT: This is Ken Shotknecht from WFTV in Orlando, Florida. Regarding targeting a launch date, first we heard late March of 1981 and then March 10 and late March again, so the question would be, why bother jockeying around just a matter of days when the Columbia itself could be sitting on the pad a couple of extra months for final checkout?

DR. FROSCH: Essentially because we have to have a continuing working schedule in order to do the detailed planning so that we work in terms of how that schedule is affected by the various events that take place, and since we have an answer to the question, we answer the question, which may be confusing but it is in fact the answer in terms of what we're doing entirely.

MR. O'DONNELL: Anymore from the Cape?

MR. HARRIS: Gordon Harris, Reuters. Does NASA plan to turn the Shuttle over to a commercial operations manager at some point?

DR. FROSCH: Well, I think turn is much too strong a word. We have looked a little bit at the question of how commercial operations might be done eventually and there have been one or two -- I was going to say vague proposals, but they were too vague to be considered proposals. As to what might happen down the line, I think that's something to be considered as we understand how the system operates and whether we see whether there is anybody who wants to do that and then there's the open question of how we would mix that kind of a commercial or semi-commercial operation with the national security aspects of the operation. So there are a number things that have to be considered before we take such a step. I don't think that's a subject for very serious consideration for several years and I think I said once before that anybody that came in and proposed at this stage to take over a commercial operation before we have an experimental flight, would be somebody I would be very suspicious of. It's sort of like Groucho Marx's comment that he didn't think he wanted to be a member of any club that would have him. (Laughter)

KSC: A final question from Peter Larson of Sentinel-Star, and that is what is LI-2200 and how much money is being spent on alternative thermal protection systems?

MR. YARDLEY: Well, the LI, I'm sure, stands for Lockheed Insulation. The 2200 stands for 22 pounds per cubic foot. That's just a numbering system that Lockheed invented. We have a million dollars planned for looking at alternative tiles in terms of metal, carbon carbon, applications and so on, that the Langley Research Center is managing independently of the ongoing tile development efforts in the actual project and we've programmed something on the order of $20,000,000 over the next several years to try to develop better tile.

MR. O'DONNELL: Okay, do we have any questions at Marshall?

MARSHALL: Marshall, we have no questions.

MR. O'DONNELL: How about Houston?

MR. MALONEY: (Jim Maloney, Houston Post) This rollout date of before November 23rd from the OPF -- is that just a matter of a few days or do you have a definite date?

DR. FROSCH: I don't think we have specific earlier date at this point.

MR. MALONEY: The last time we met on August 1, Dr. Frosch, you were asked about the cost overrun, what the amount was, and you replied that you had been too busy with technical questions to concern yourself about that. Could you tell us today what the cost overruns are on the Shuttle?

DR. FROSCH: Cost overrun for what as measured against what. The baseline number that we have used has been the cost of development in '72 dollars and in that computation, the baseline number was about 5.15 billion and the last number I recall in '72 dollars was about 6.3 or 6.4 billion. And that you will have to recalibrate to later inflated dollars. I always do it wrong.

MR. O'DONNELL: That voice must have been Jim Maloney of the Houston Post. Am I right?

MR. MALONEY: Yes, Bill.

MR. O'DONNELL: Any more questions from Houston?

HOUSTON: That's it Bill.

MR. O'DONNELL: How about Dryden?

DRYDEN: Dryden has no questions.

MR. O'DONNELL: Okay, we'll return here to Headquarters and wrap up a few questions. Right here, Althea.

MR. FAUQUEAUX: Didier Fauqueaux, Agence France Presse. A question to Dr. Frosch. There are reports saying that the Pentagon is unhappy about NASA management about the Shuttle program and should be in control of the program because of conflicting military and civilian interests. Could you comment on that?

DR. FROSCH: Yes, well I'll start my comment by making a comment based on my own experience of having worked in the Pentagon for nine and a half years. The Pentagon is a building with 25,000 people in it. It has nearly that many opinions on any given subject. So you have to say who. I think there are certainly people in the Defense system who feel that from the very beginning it should have been done as a military system. I don't think the sort of formal senior management feels that particularly. I think we have a good operating interface. It is characteristic of military systems and security systems that the people responsible for them feel that they would like to be in charge of the systems that they use. I think that that's kind of a reasonable point of view from their position of responsibility.

A definite decision was made and has been remade with the agreement and cooperation of the senior managers in the Defense Department that this will be managed as a national system -- that NASA will be the developer and operator of the system and that we will cooperate in using it. It's important to know that in the use and in the particular Defense Department flights that the Defense Department will be controlling the flight and the system.

MR. O'DONNELL: Any other questions here? David?

MR. DOOLING: Back on the managing for a moment, John. When do you expect the main propulsion tests to resume, how many more do you have in the series, when do you expect them to conclude and how much padding to you have between that and first launch?

MR. YARDLEY: One November is our schedule for the next MPT. Then we'll schedule one for 1 December. If both of those go letter perfect, we may quit there. We have another scheduled on December 31st or January 1st, which is a contingency backup. Let's say we have to make all three; I still have got three months cushion.

MR. O'DONNELL: Okay, third row there.

MS. JABS: Cynthia Jabs, Fairchild Publications. I wonder if you could say what innovations of the process of the Shuttle development you would call the most revolutionary? I don't think we have anything quite like rubber here, but what -- and you also said it's important to look at it as a system innovation -- but what are some of the innovations here that you expect are likely to be most useful?

DR. FROSCH: Let me try it, John. You may want to add some. I think that the tile material itself will turn out to be of more general use than just the use we're making of it because they're rather extraordinary insulating material. I don't see it going into houses very soon at the price, of course, but for industrial purposes, it may begin to have some uses. I think the total control of the engines and the entire flight system as a computer-controlled fly-by-wire system is certainly a major innovation or at least a demonstration of an important innovation. In rocket engine terms, the engines themselves and the way in which they have been compressed, in both size and weight, is clearly a major innovation but whether that flows over into other things isn't clear, although it will probably have some effect on turbine engines. Generally, and certainly, the computer control techniques that have been developed for this engine are going to be useful in general engine operation. There are undoubtedly some structural things, although as John said, that is principally a conventional structure. I don't know, what you would add...

MR. YARDLEY: The structural composites certainly add to the storehouse of knowledge. There are other airplane programs about in the same stage as we are -- they haven't built quite as big stuff. I think you hit most of them.

MR. O'DONNELL: Questions? Back here, Mark Kramer.

MR. KRAMER: Mark Kramer, CBS. Dr. Frosch, in your vugraph dealing with launch cost comparisons, I just want to make sure I understand the numbers here. Does this assume a shared payload bay and....

DR. FROSCH: This assumes a shared payload bay and, in fact, that's why there's a difference between vertical and inclined because that's the charge based on the fraction of payload bay that's being used. The assumption is the rest of the payload bay will be used b somebody else, but the charge to this user doesn't depend on that.

MR. KRAMER: And what is the present estimate for the total cost of dedicated flight?

DR. FROSCH: Total cost of a dedicated, again I'll calibrate it by dollars of a particular year, at '75 dollars, the estimate is about $22 million.

MR. KRAMER: And that's what this estimate is, '75 dollars, the one on the vugraph?

MR. YARDLEY: That one's 78.

DR. FROSCH: This one's '78 dollars.

MR. KRAMER: Okay.

DR. FROSCH: So, there's some translation....

MR. YARDLEY: Probably 27 or 28 million....

DR. FROSCH: Probably 27 or 28 in '78.

MR. KRAMER: Okay. A final question. We heard figures for a number of flights that you can expect the engines to last and the TPS. What is the number of flights you expect the main air frame, the entire structure, to be reusable?

DR. FROSCH: We've assumed 100 flights.

MR. KRAMER: Thank you.

MR. O'DONNELL: Okay, Ken Silverstone here.

MR. SILVERSTONE: Ken Silverstone, Defense Daily. Dr. Yardley, could you go over again the reusability estimates on the tile itself on the Orbiter 101? You talked about the carbon carbon 40 or 50, but how about the tiles themselves?

MR. YARDLEY: Well the tiles themselves have been run through 200 flight heating profiles without any damage. Now what I referred to in the tiles that we're not sure of yet and we haven't finished all the testing, is whether or not they can go through the vibrations and so on and that the felt will not get too loose, so that we'll have to replace the felt. That's an open question and some of the tests that we're planning in December and January are going to put some light on it. There's not much worry about them for a dozen flights, say, but we do have to do some more testing to know how long they're going to last.

MR. O'DONNELL: Okay. Well, thank you very much and please don't forget to self-address an envelope back there.

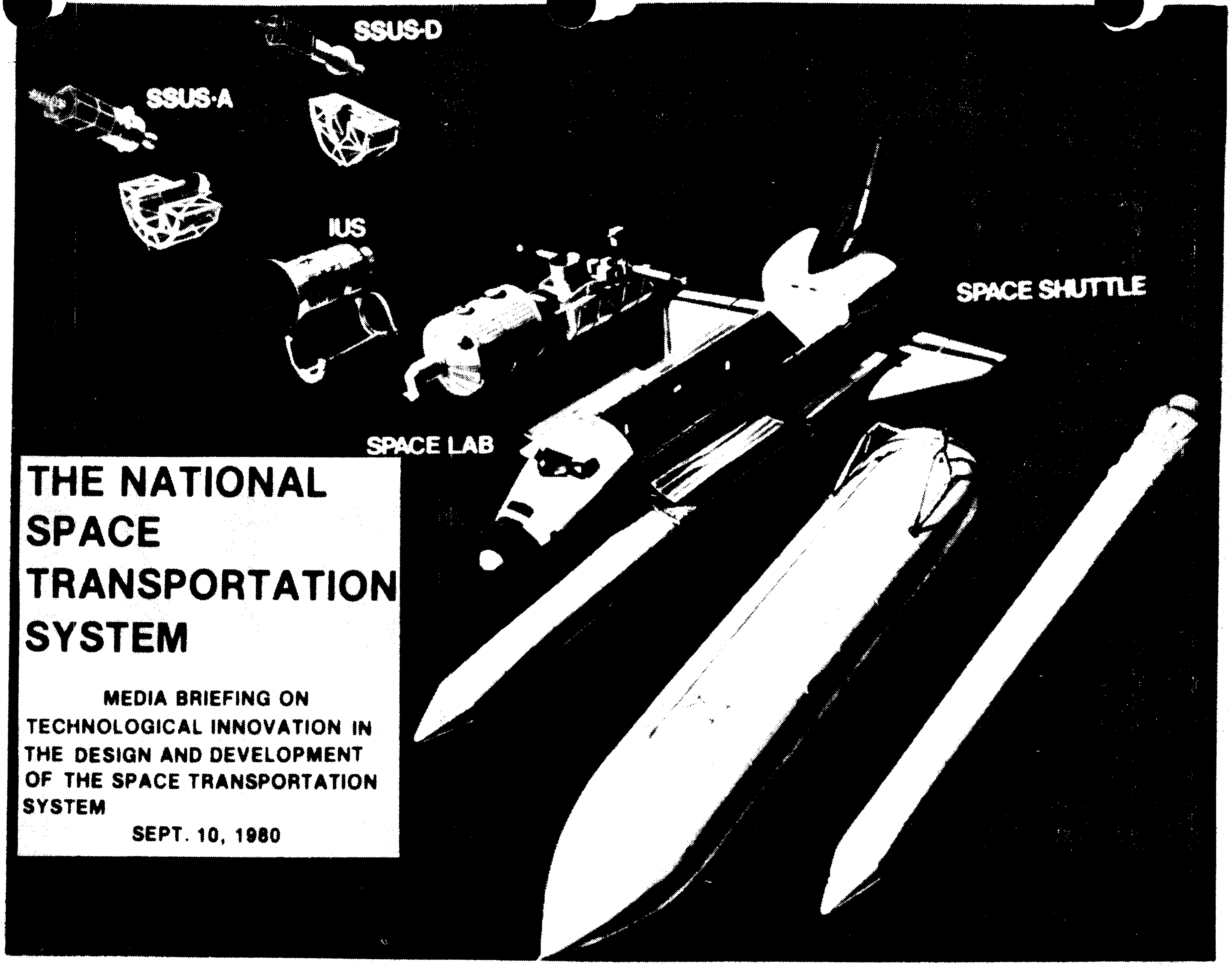
-end-

Space Transportation System

Press Briefing

Dr. Robert A. Frosch

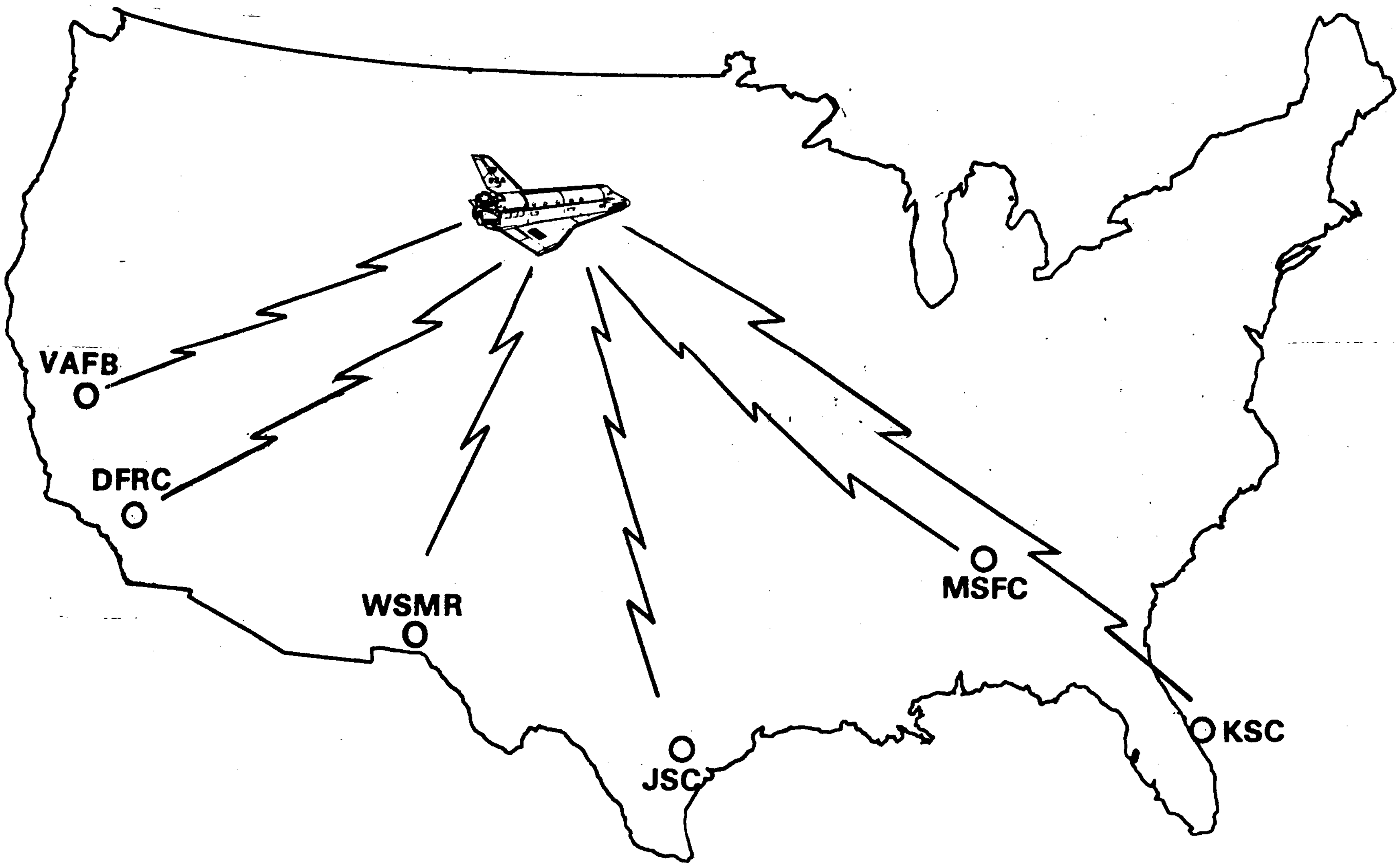
September 10, 1980



THE NATIONAL SPACE TRANSPORTATION SYSTEM

MEDIA BRIEFING ON
TECHNOLOGICAL INNOVATION IN
THE DESIGN AND DEVELOPMENT
OF THE SPACE TRANSPORTATION
SYSTEM

SEPT. 10, 1980



NASA HQ LF80-3934 (1)
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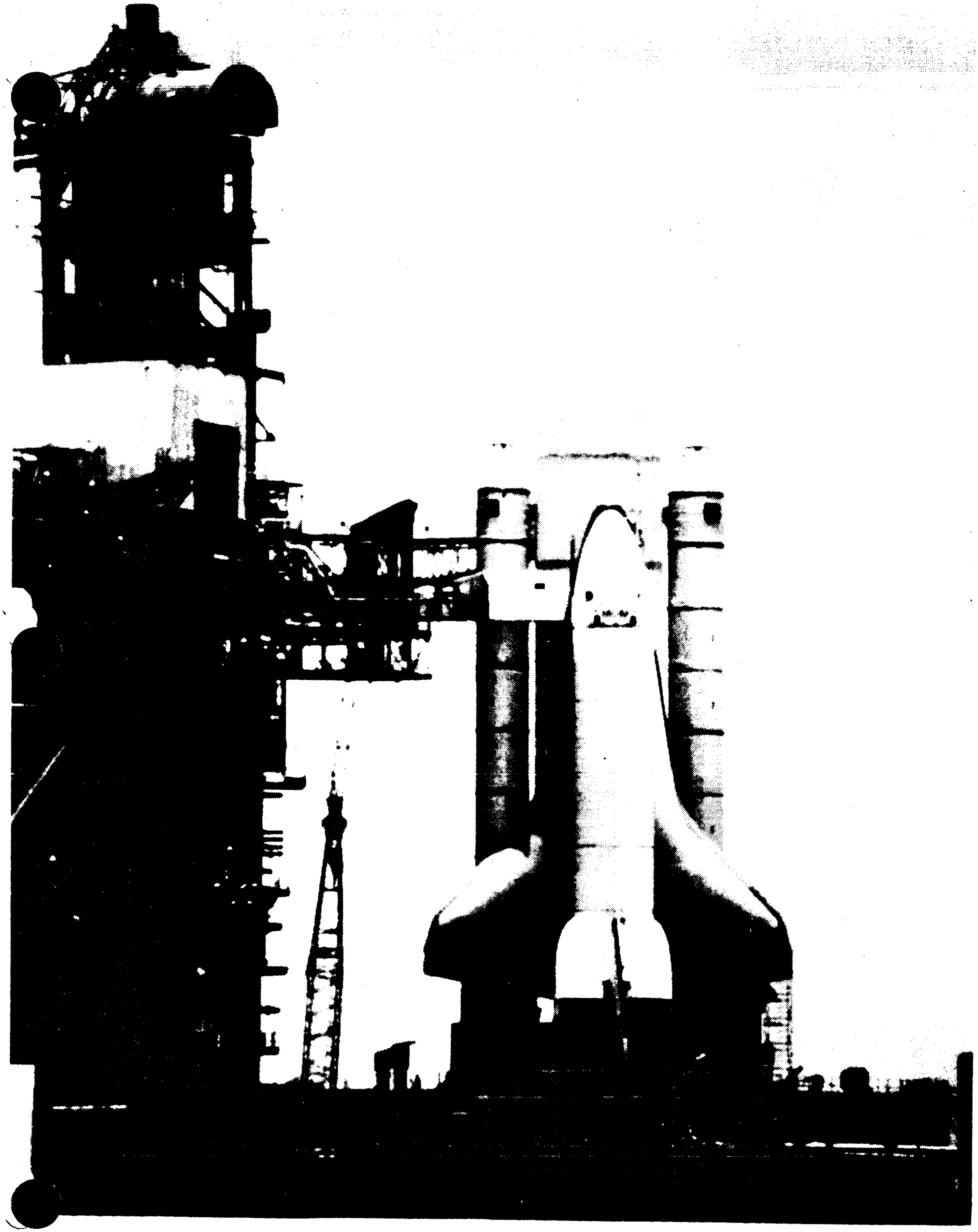
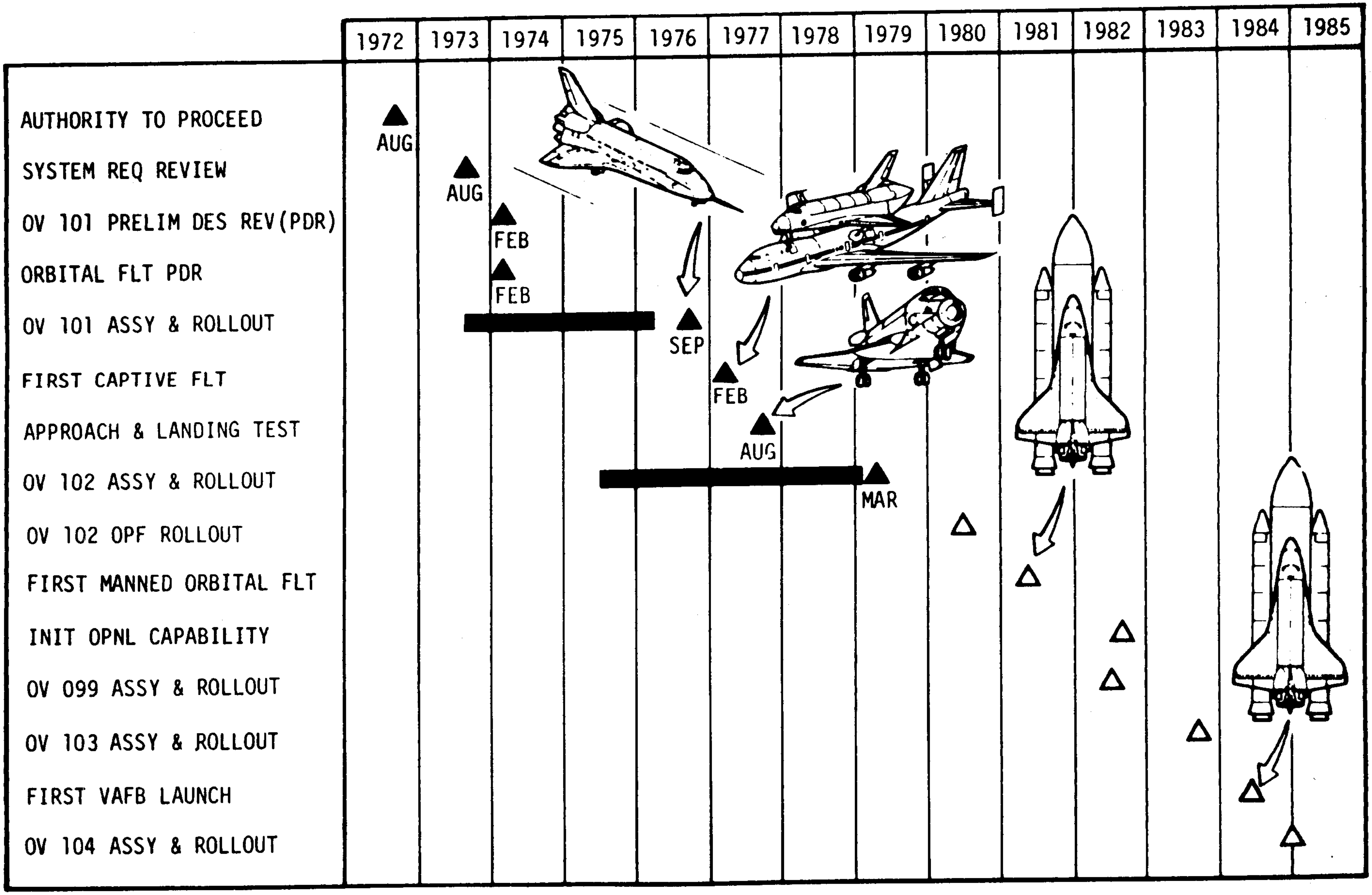
SPACE TRANSPORTATION SYSTEM

ELEMENTS

- SPACE SHUTTLE
  - ORBITER
  - EXTERNAL TANK - ET
  - SOLID ROCKET BOOSTERS (2) - SRB
  - SPACE SHUTTLE MAIN ENGINE (3) - SSME
  - GROUND AND LAUNCH SYSTEMS
- UPPER STAGES
  - INERTIAL UPPER STAGE - IUS
  - SPINNING SOLID UPPER STAGES - SSUS-A/ -D
  - FUTURE ORBITAL TRANSFER SYSTEMS - OTV, MOTV
- SPACELAB
  - PRESSURIZED MODULE
  - PALLET SEGMENTS
- TRACKING AND DATA RELAY SATELLITE SYSTEM - TDRSS
- PERFORMANCE AUGMENTATION SYSTEMS
  - POWER EXTENSION PACKAGE - PEP (under early development)
  - LIQUID BOOST MODULE - LBM (under early development)
  - 25 kW POWER SYSTEM - PS (in planning)
  - ADVANCED ORBITAL CAPABILITY SYSTEMS (in planning)



Space Shuttle Program Milestones



SPACE SHUTTLE

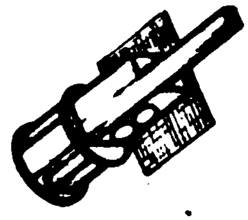
PROGRAM OBJECTIVE

- PROVIDE A NATIONAL SPACE TRANSPORTATION SYSTEM WHICH IS MORE ECONOMIC THAN PREVIOUS SYSTEMS, AND WHICH HAS NEW CAPABILITIES NOT ACHIEVABLE WITH PREVIOUS SPACE LAUNCH SYSTEMS:
    - REUSABILITY
    - RELIABILITY
    - VERSATILITY
    - FLEXIBILITY
    - ECONOMY & EFFICIENCY
    - EVOLUTIONARY POTENTIAL

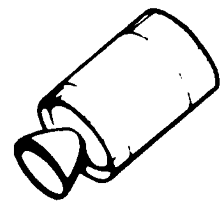
WHAT THE SPACE SHUTTLE CAN DO

USES

- DELIVERY & PLACEMENT IN EARTH ORBIT OF:
  - SATELLITES
  - PROPULSION STAGES
  - OTHER PAYLOADS OR CARGO
- RETRIEVAL OF EXPENSIVE PAYLOADS FOR REUSE
- SERVICE & REFURBISHMENT OF SATELLITES IN SPACE
- TRANSPORT TO ORBIT, OPERATE, & RETURN:
  - SPACE LABORATORIES
  - SHORT DURATION PAYLOADS
- SAFE, COMFORTABLE TRANSPORT OF PASSENGERS
- LABORATORIES FOR RESEARCH IN:
  - MEDICAL & HEALTH CARE
  - MATERIALS
  - MANUFACTURING PROCESS
  - BIOLOGICAL & LIFE SCIENCES
  - SPACE PHYSICS
  - ADVANCED TECHNOLOGY
- SCIENCE SATELLITES IN:
  - ASTRONOMY & PHYSICS
  - PLANETARY EXPLORATION



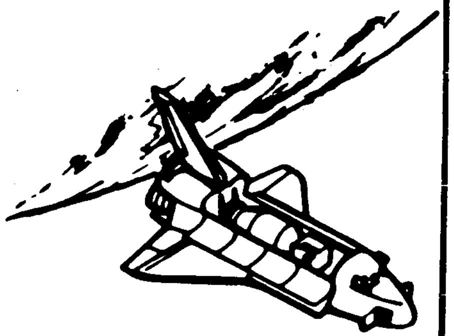
SATELLITES



PROPULSION STAGES

OPERATIONS

- EARTH RESOURCE EXPLORATION, INVENTORY, & DEVELOPMENT IN:
  - GEOGRAPHY & CARTOGRAPHY
  - AGRICULTURE, FORESTRY & RANGE
  - HYDROLOGY & WATER POLLUTION
  - MINERALS & FUELS
  - OCEANOGRAPHY
  - LAND USE & PLANNING
- COMMUNICATIONS
- NAVIGATION
- METEOROLOGY & WEATHER
- GEODETICS
- NATIONAL SECURITY
- SPACE STATION LOGISTICS
- PAYLOADS FOR NEW OR UNFORESEEN PROBLEM SOLUTION



LABORATORIES

SPACE SHUTTLE ADVANTAGES

("WHY SHUTTLE?")

- REDUCTION OF COST OF TRANSPORTATION TO/FROM ORBIT, AND OF SPACE OPERATIONS
- FLEXIBILITY OF LAUNCHING A WIDE VARIETY OF DIFFERENT PAYLOADS:
  - APPLICATIONS SATELLITES
  - SCIENCE INSTRUMENTS AND PLATFORMS
  - LABORATORY MODULES
  - CONSTRUCTION FACILITIES, TOOLS, etc.
  - ELEMENTS OF LARGE STRUCTURES
  - UPPER STAGES
  - CIVILIAN AND MILITARY CREWS AND CREW SYSTEMS
- LAUNCH OF HEAVIER AND LARGER PAYLOADS INTO LOW EARTH ORBIT THAN WITH MOST PAST EXPENDABLE SYSTEMS
- INTRODUCTION OF NEW OPERATING CAPABILITIES NOT POSSIBLE WITH PAST SYSTEMS:
  - MANNED SUPPORT OF ORBITAL R&D
  - SATELLITE REPAIR, MAINTENANCE, AND RETRIEVAL
  - LARGE STRUCTURES FABRICATION, ASSEMBLY, AND SERVICING
  - ORBITAL OPERATIONS (OTV SERVICING AND FUELING, etc.)
- FOSTERING OF TECHNOLOGICAL INNOVATION AND SOCIAL PROGRESS BY STIMULATING ORDER-OF-MAGNITUDE EXPANSION IN SPACE R&D PARTICIPATION BY INDIVIDUALS, INDUSTRY, AND INTERNATIONAL GROUPS
- PROVISION OF FOUNDATION AND EVOLUTIONARY ELEMENT OF FUTURE SPACE SYSTEMS ABLE TO MEET GROWING NEEDS FOR LARGER MASS ON ORBIT, MORE POWER ON ORBIT, AND LONGER STAY-TIMES ON ORBIT

MISSION CAPABILITIES

- MISSION DURATION

  BASELINE –7 DAYS WITH 4 CREWMEN
  WITH KITS – UP TO 30 DAYS WITH UP TO 7 CREWMEN

- MISSION STATIONS

  COMMANDER
  PILOT
  MISSION SPECIALIST
  PAYLOAD SPECIALISTS – UP TO 4

- CREW/PASSENGER PROVISIONS

  NORMAL EARTH ATMOSPHERE

  CONTROLLED ENVIRONMENT

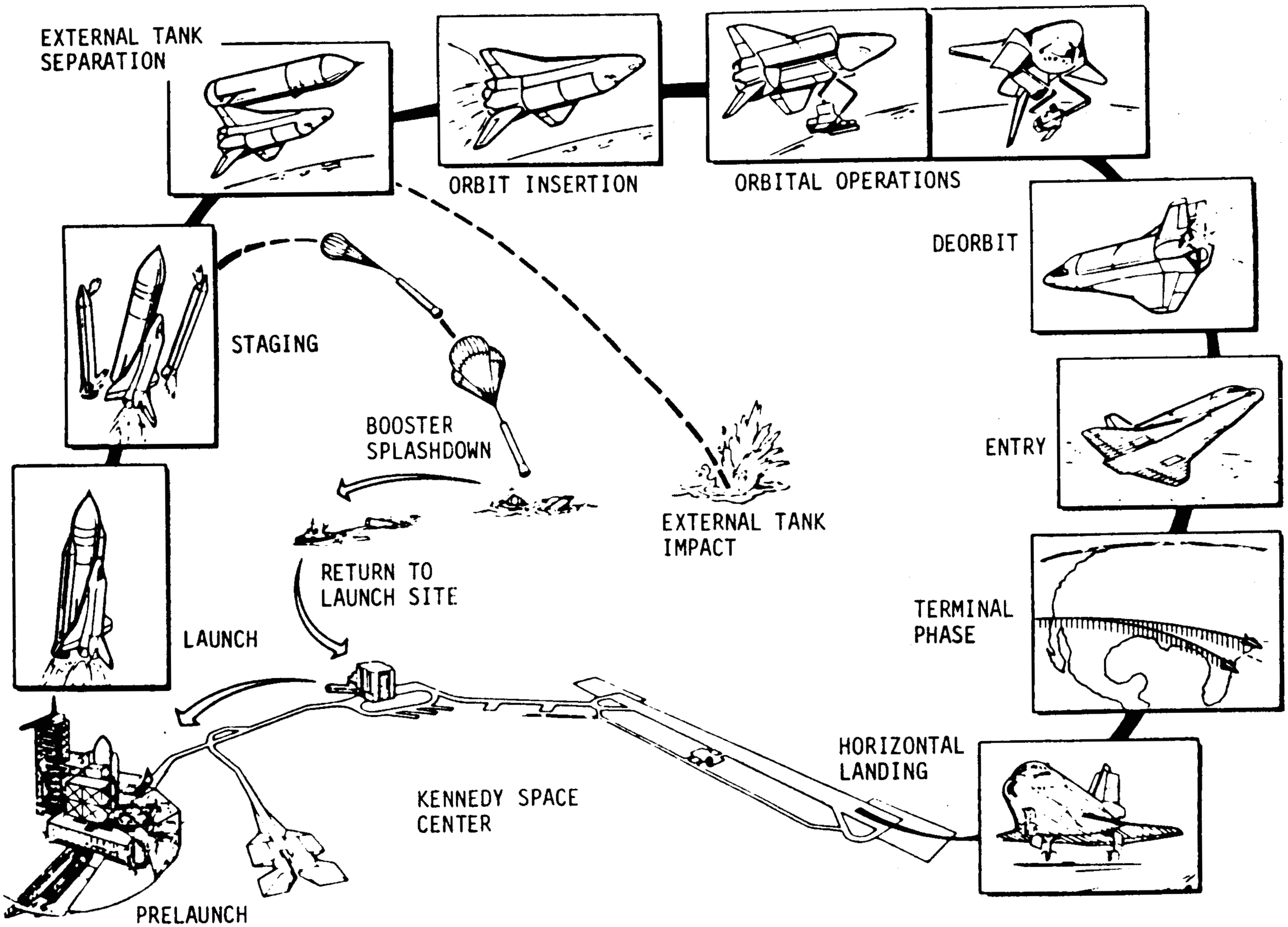
  HOT AND COLD FOOD

  MALE AND FEMALE HYGIENE FACILITIES
  3G MAXIMUM ACCELERATION

- SPACE SUIT OPERATIONS FOR PAYLOAD SUPPORT AND RESCUE

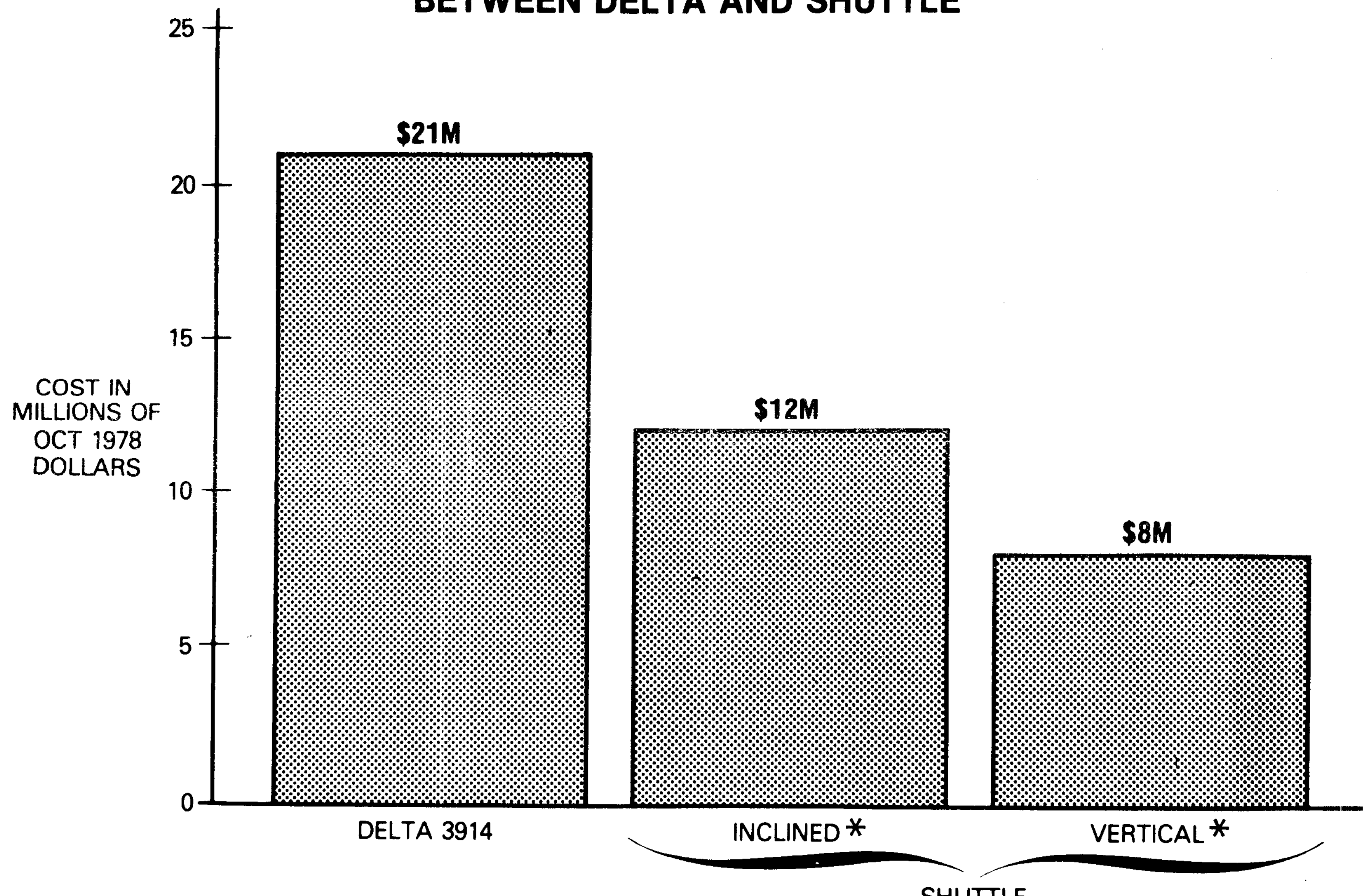
NASA HQ MH74-5989
REV. 2-4-75

Typical Mission Profile

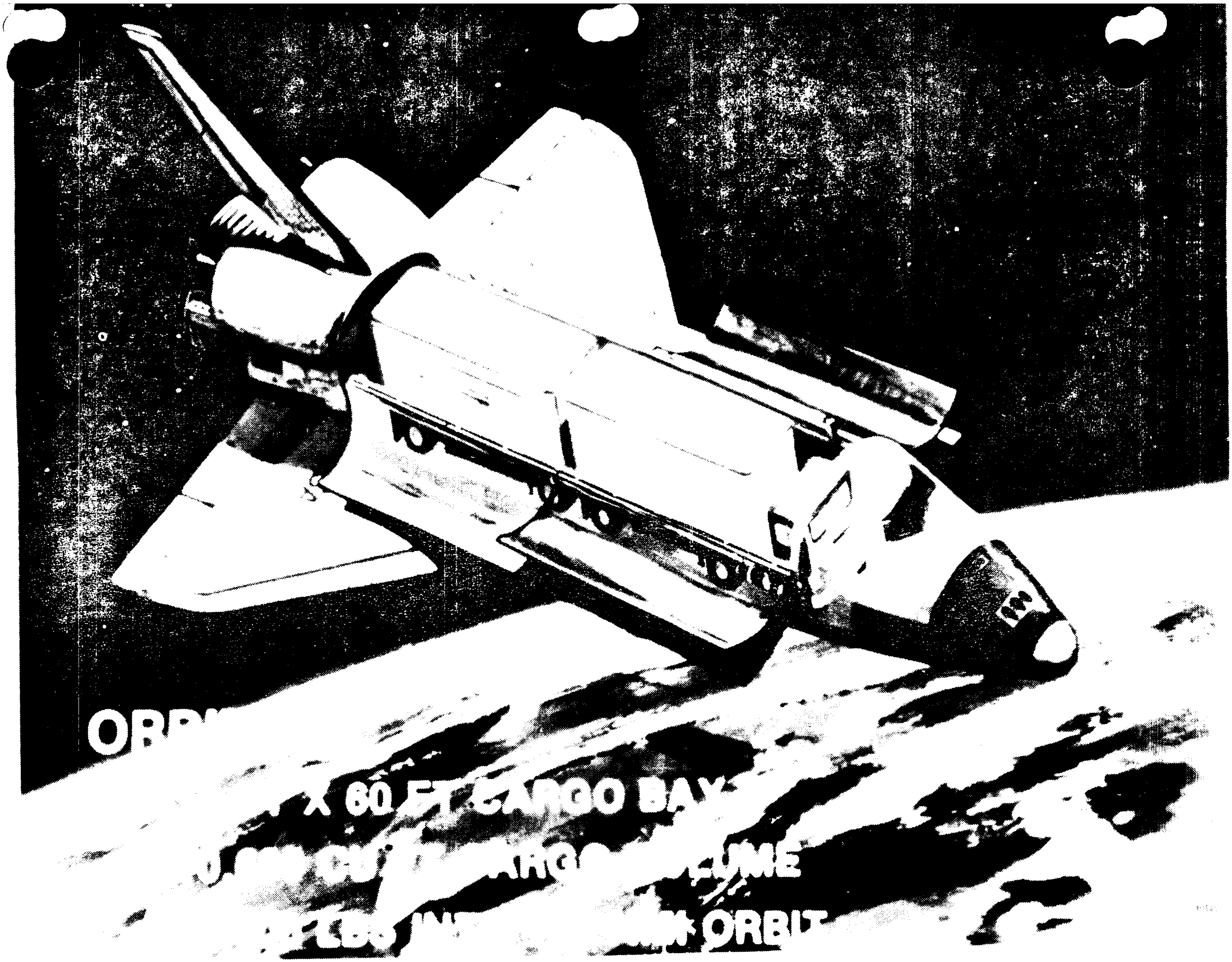


LAUNCH COST COMPARISONS

BETWEEN DELTA AND SHUTTLE



* PAYLOAD ARRANGEMENT IN CARGO BAY

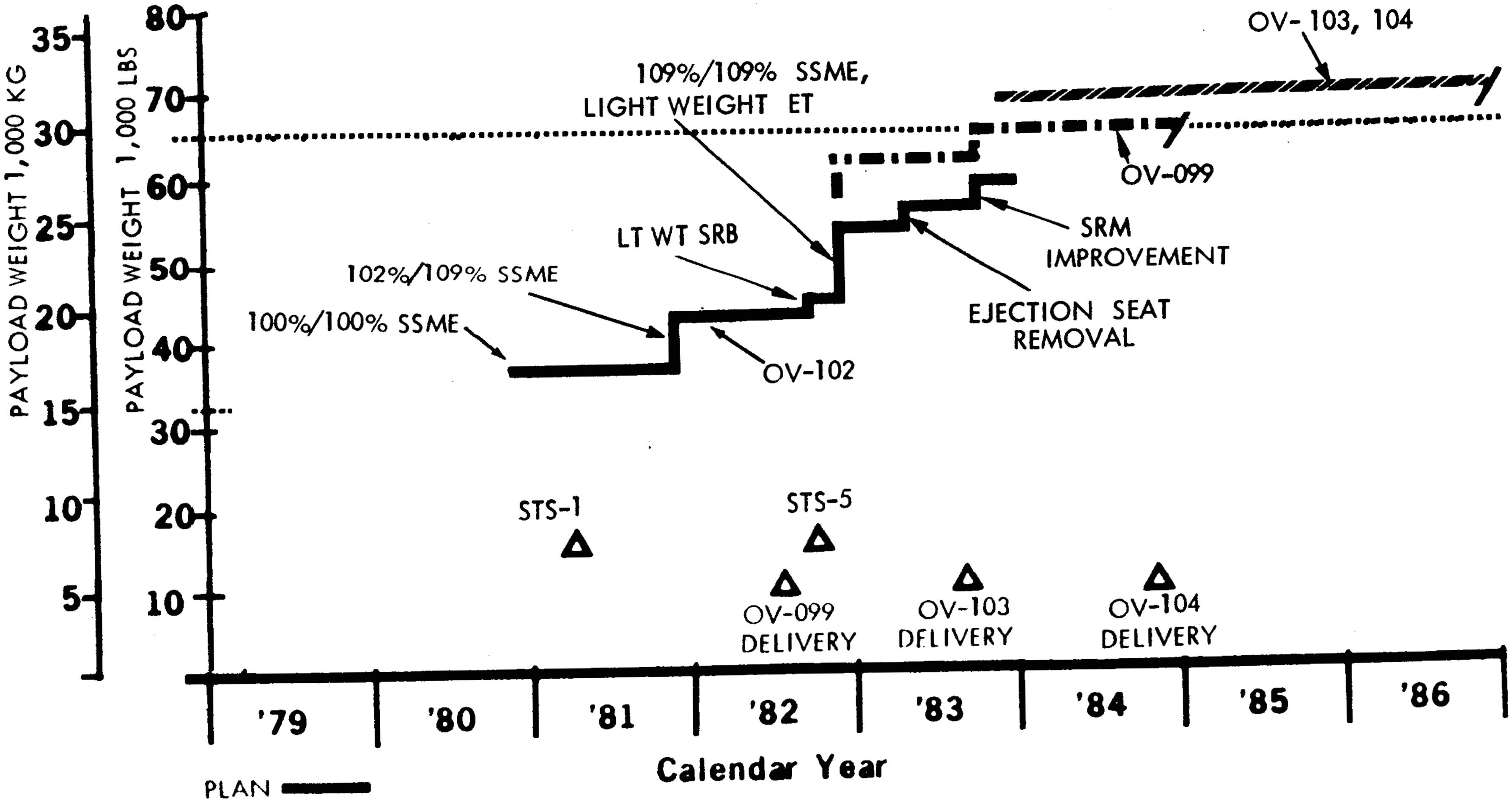

OR
X 60
CARGO BAY
UME
ORBIT

SPACE SHUTTLE CAPABILITY EVOLUTION

Eastern Test Range (ETR)

SEPT 10, 1980

- 2 MEN/1 DAY
- 275 KM (150 NM) CIRCULAR ORBIT

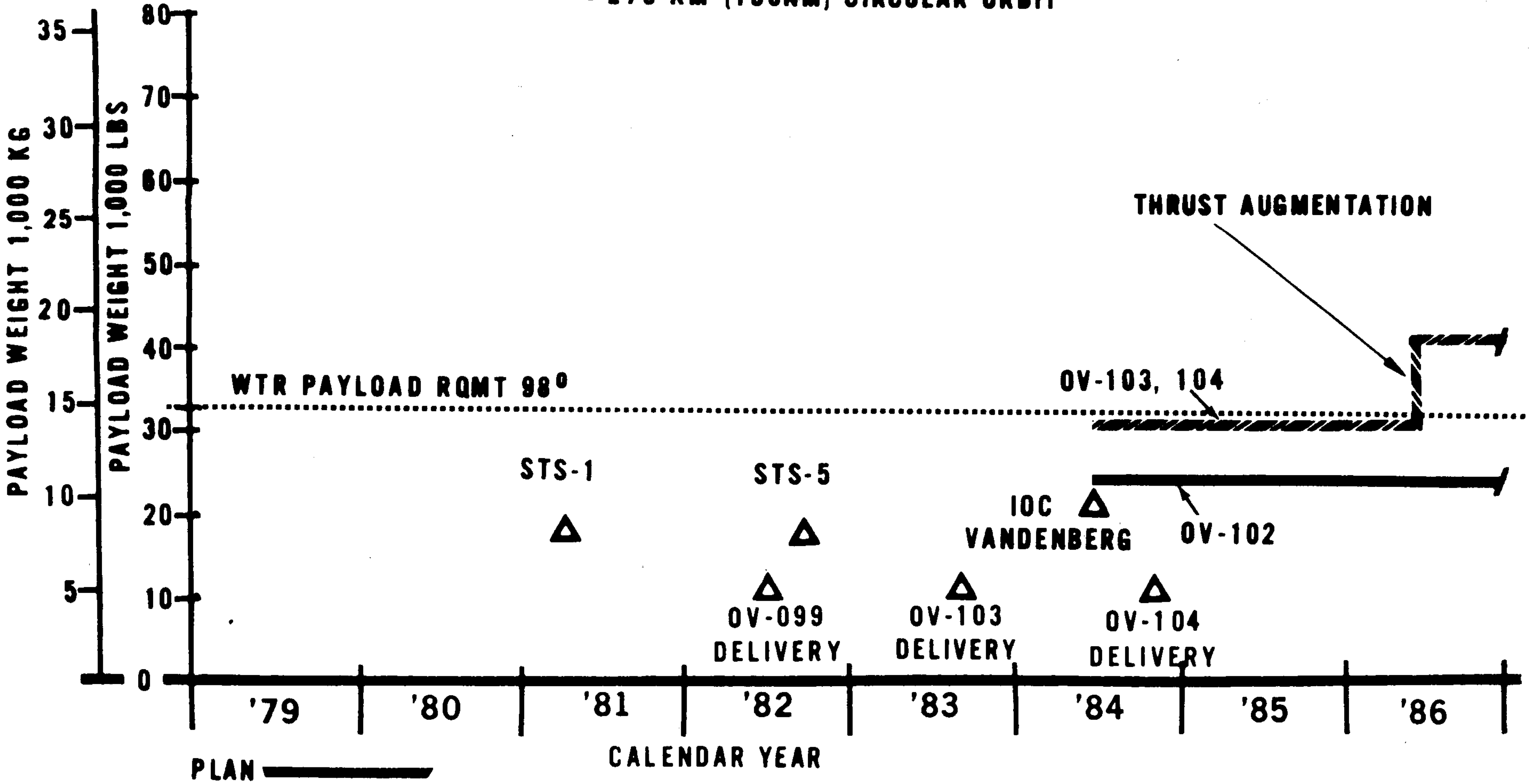


SPACE SHUTTLE CAPABILITY EVOLUTION

Western Test Range (WTR)

SEPT 10, 1980

- 2 MEN/1 DAY
- 275 KM (150NM) CIRCULAR ORBIT

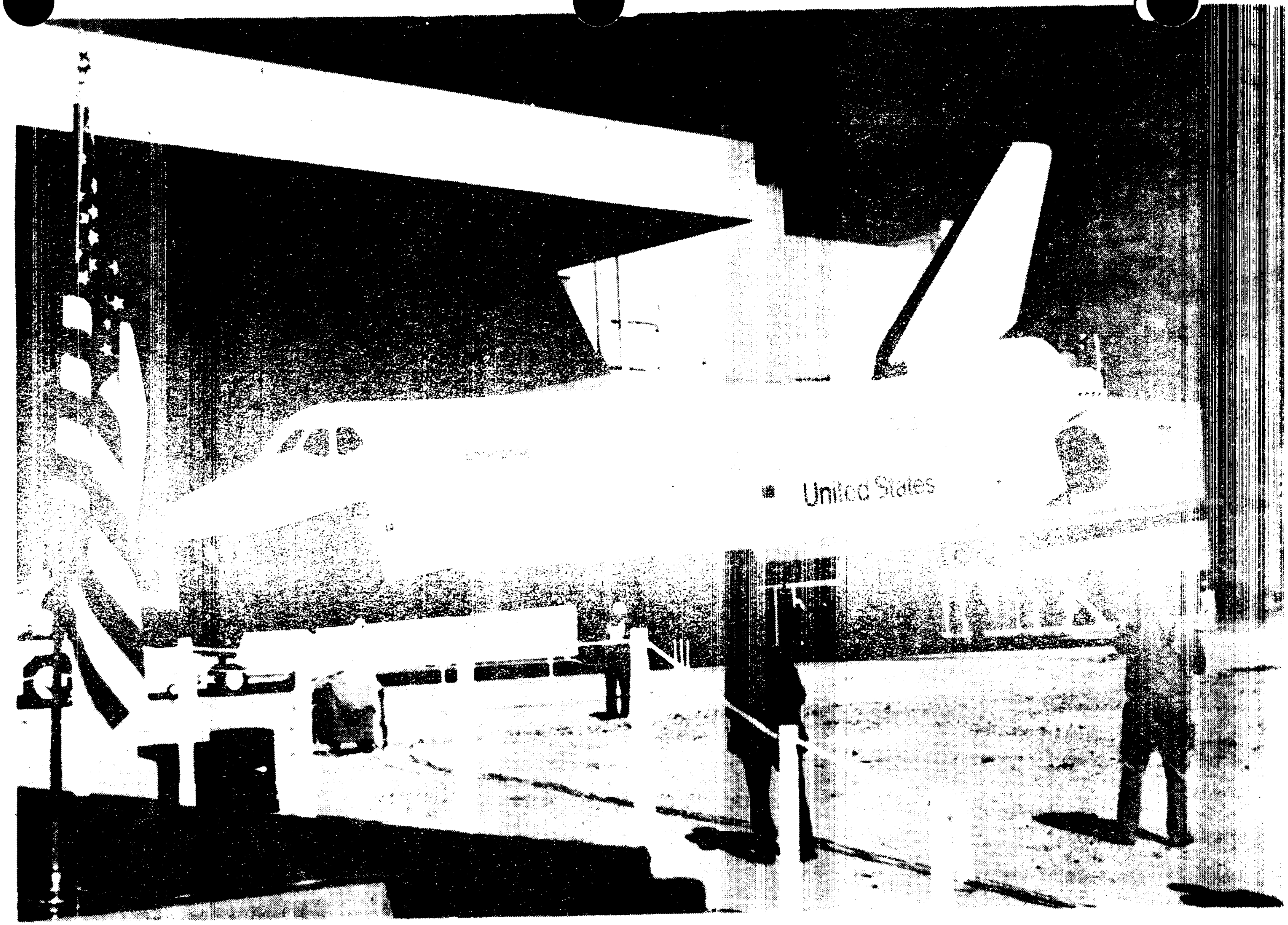


Space Transportation System

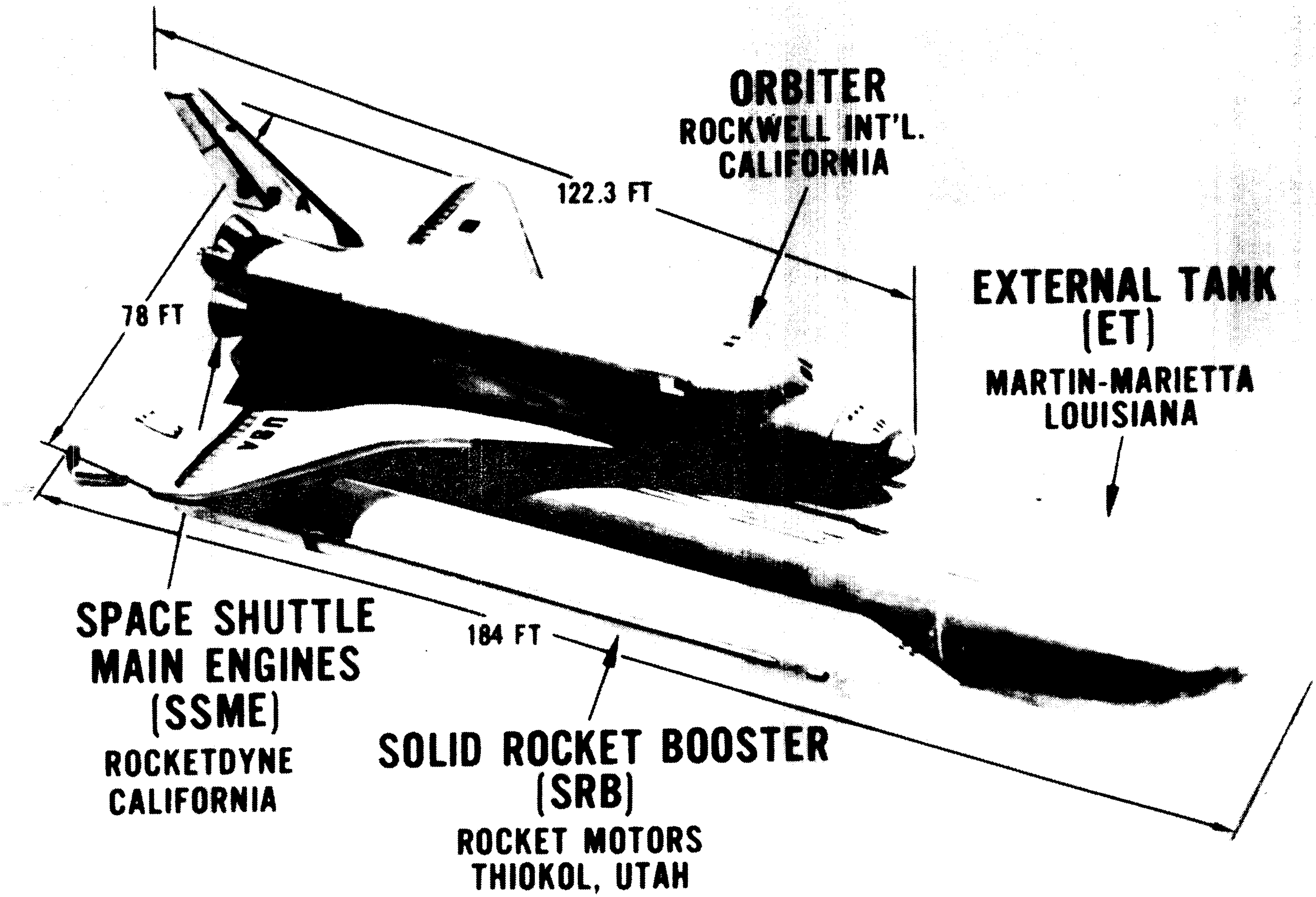
Press Briefing

John F. Yardley

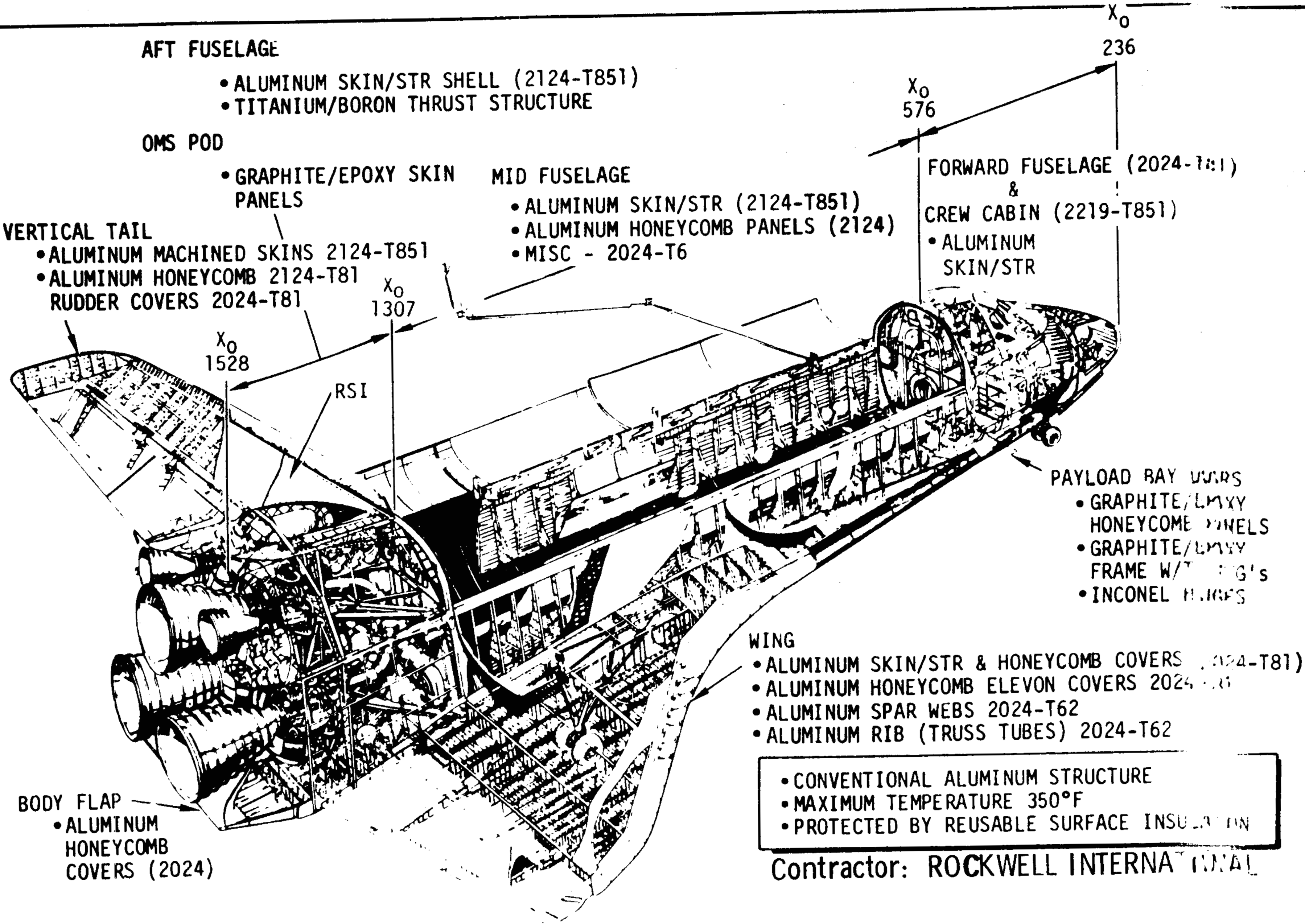
September 10, 1980


United States

SPACE SHUTTLE SYSTEM



Orbiter Structure



Contractor: ROCKWELL INTERNA

5

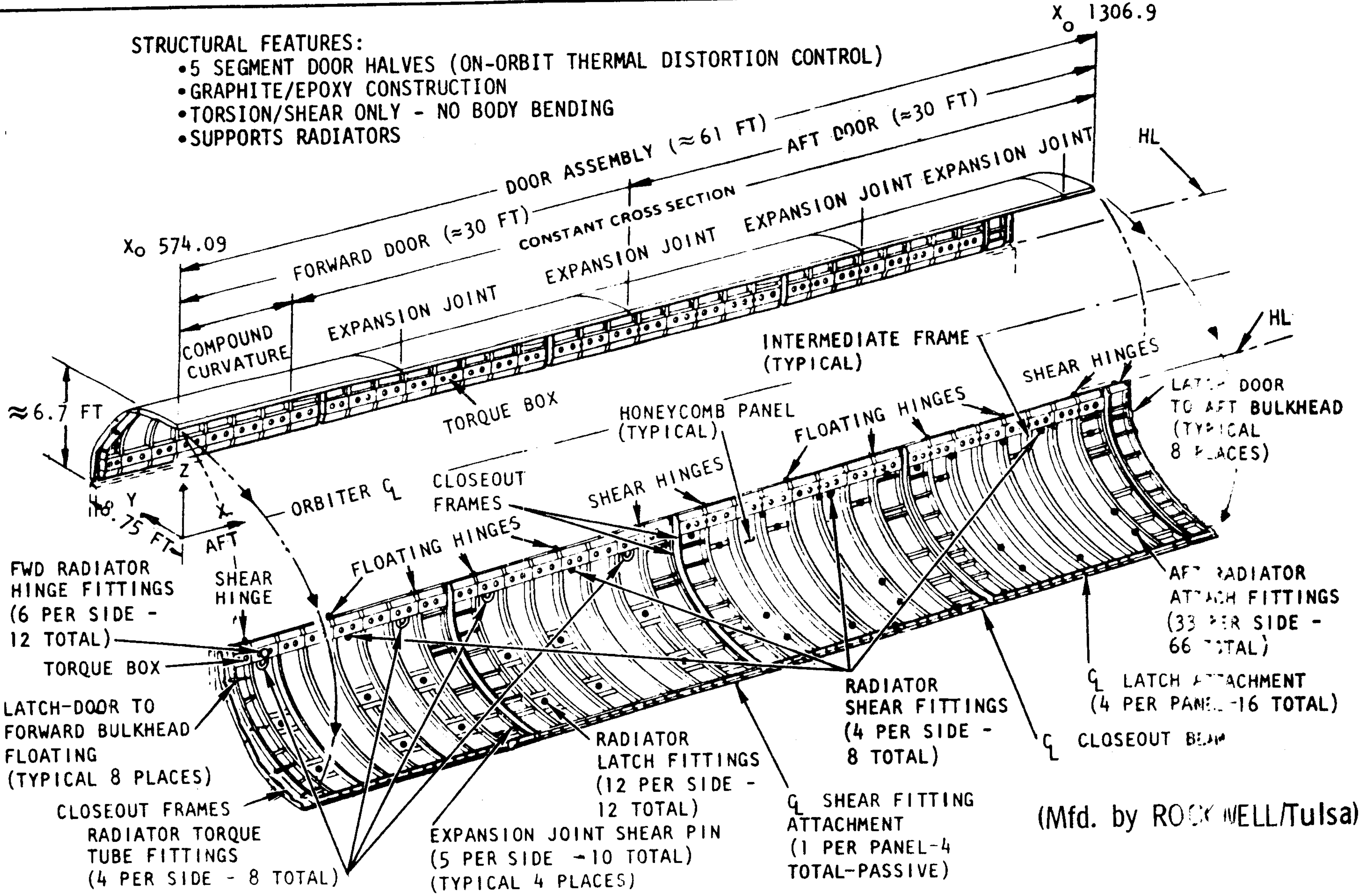
PAYLOAD BAY DOORS

TECHNOLOGY INNOVATION

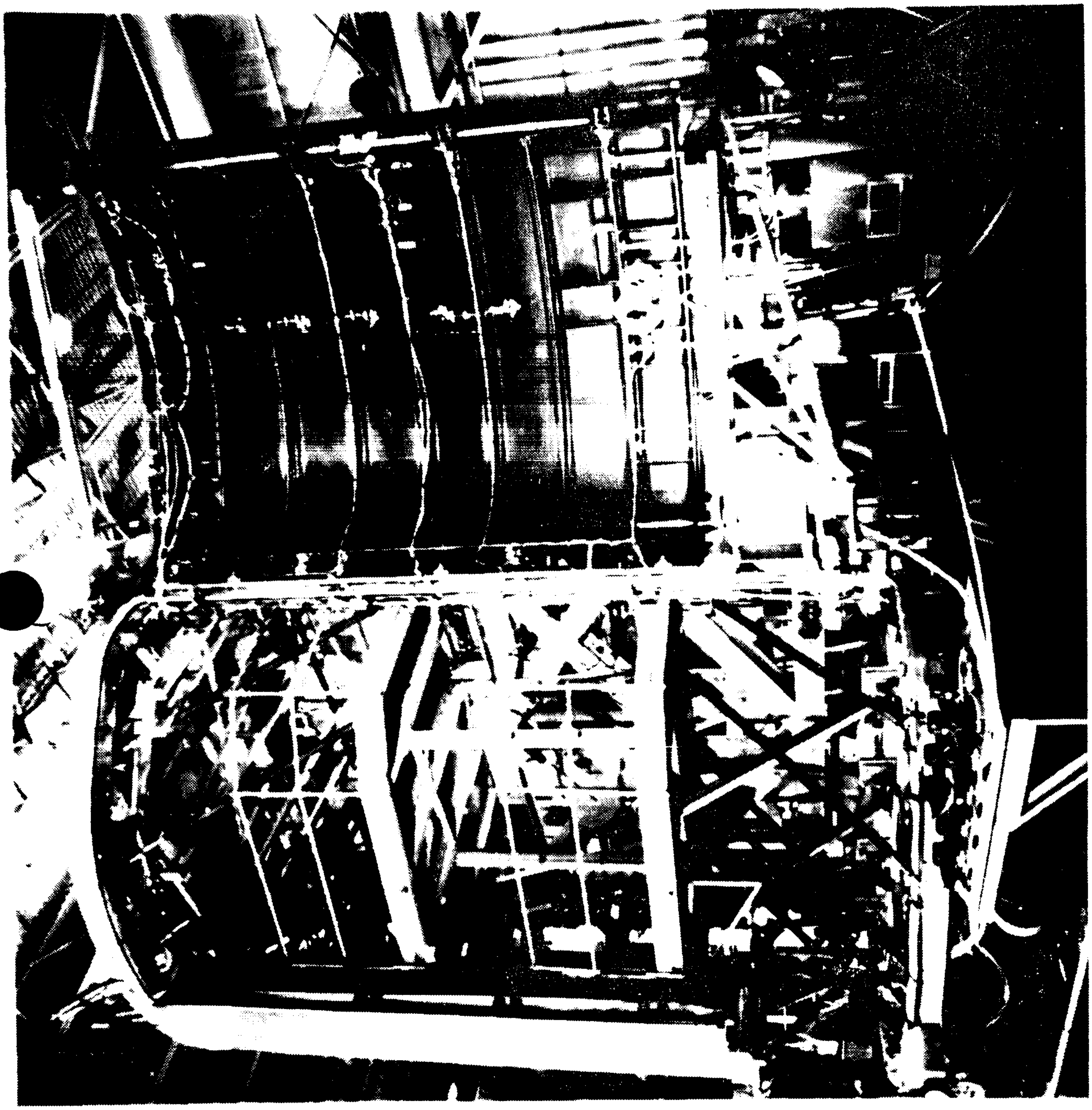
- COMPOSITE MATERIALS
  - DESCRIPTION:
    - EACH DOOR IS 61 ft LONG, CONSISTS OF 5 SECTIONS
    - TOTAL SURFACE AREA 1600 square feet
    - DOORS CARRY FUSELAGE TORSION, NO BENDING
    - RADIATORS MOUNTED INSIDE, TPS INSULATION OUTSIDE
  - CONSTRUCTION:
    - HONEYCOMB AND FRAMES OF COMPOSITE MATERIALS
      - FACE SHEETS (.016) OF GRAPHITE/EPOXY
      - CORE (.60) IS NOMEX HONEYCOMB, ADHESIVELY BONDED TO FACE SHEETS
      - FRAMES ARE GRAPHITE/EPOXY TAPE AND FABRIC LAYUPS
  - ADVANTAGE:
    - WEIGHT SAVING OF 900 lbs IN 3000 lbs STRUCTURE

Payload Bay Door

STRUCTURAL FEATURES:
- 5 SEGMENT DOOR HALVES (ON-ORBIT THERMAL DISTORTION CONTROL)
- GRAPHITE/EPOXY CONSTRUCTION
- TORSION/SHEAR ONLY - NO BODY BENDING
- SUPPORTS RADIATORS



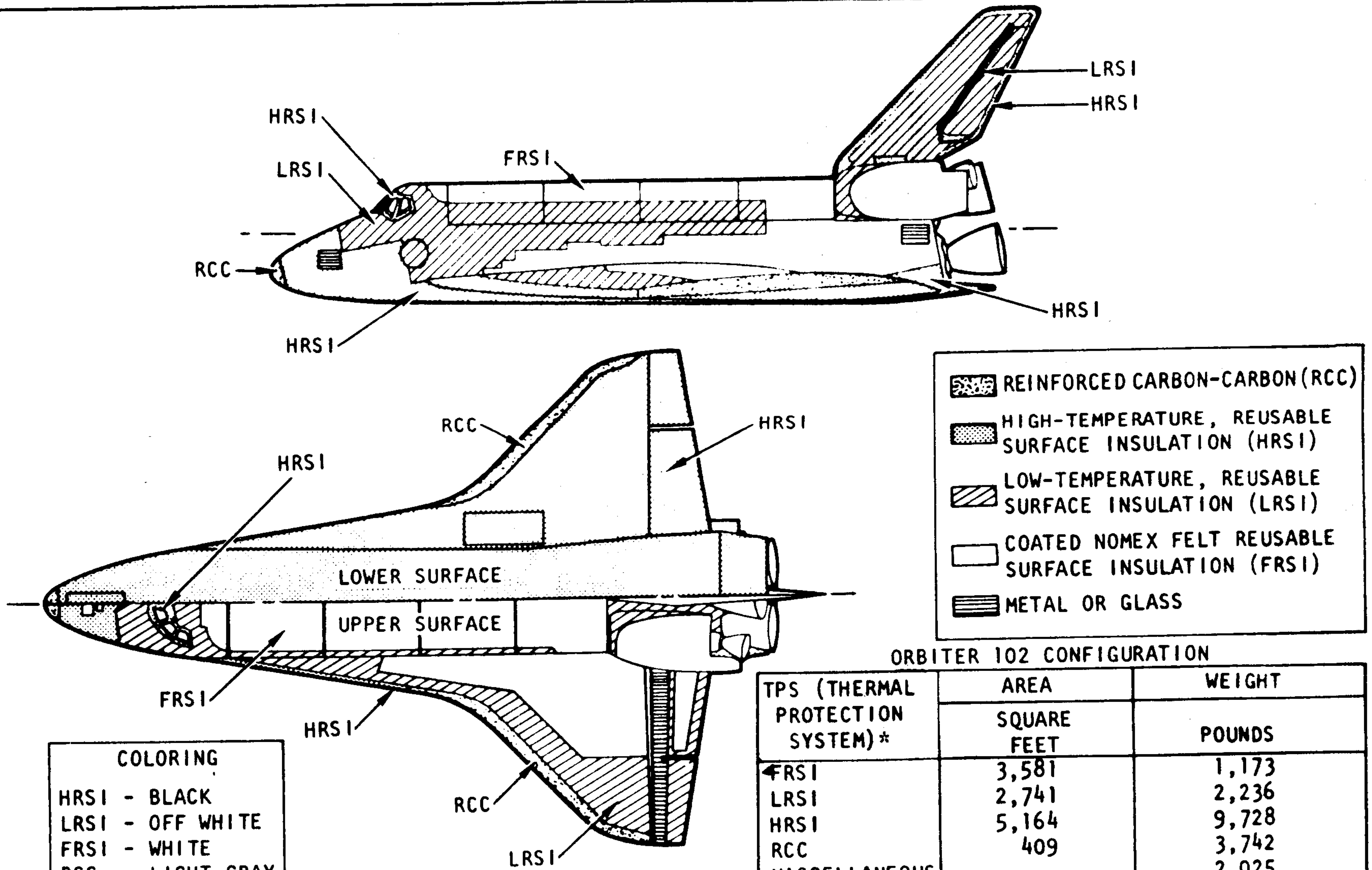
(Mfd. by ROCKWELL/Tulsa)



THERMAL PROTECTION SYSTEM (TPS)

- PASSIVE SYSTEM - RERADIATES ~90% OF HEAT LOAD; INSULATES AGAINST ~5%
- MATERIALS DEVELOPED FOR SPECIFIC PROBLEMS:
  - PYROLIZED CARBON WITH INERT SILICON CARBIDE COATING (Mfd. by VOUGHT)
    - RETAINS STRENGTH AT TEMPERATURE FOR HIGH AERODYNAMIC LOADS AT NOSE AND LEADING EDGE
    - USED AT HIGHEST HEATING AREAS (3100^{0} F)
  - HIGH-TEMPERATURE TILE (BLACK) (Mfd. by LOCKHEED)
    - USED OVER LARGEST AREA
    - VERY LIGHT WEIGHT (9 lbs/cu. ft.)
    - EXTREMELY GOOD INSULATOR AT ALTITUDE
    - SPECIAL COATING TO REJECT HEAT AND SURVIVE 2600^{0} F
  - LOW - TEMPERATURE TILE (WHITE) (Mfd. by LOCKHEED)
    - THINNER TILE FOR LEE-SIDE WITH WHITE COATING TO FACILITATE PASSIVE THERMAL CONTROL WHILE ON ORBIT
  - FLEXIBLE REUSABLE SURFACE INSULATION (FRSI)
    - COATED NOMEX FELT FOR AREAS LESS THAN 700^{0} F (Mfd. by GLOBE ALBANY)

Thermal Protection Subsystem



COLORING

HRSI - BLACK
LRSI - OFF WHITE
FRSI - WHITE
RCC - LIGHT GRAY

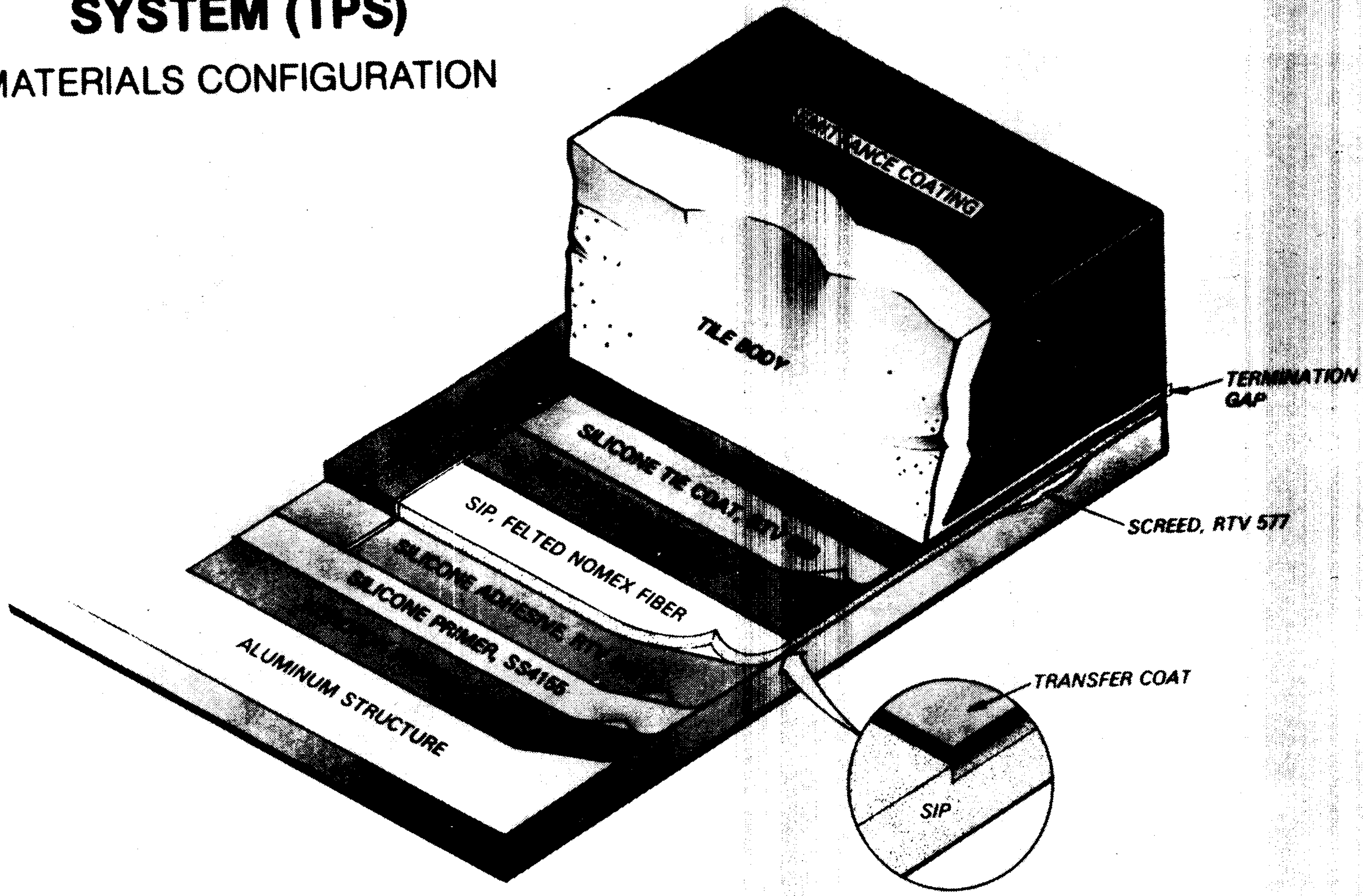
ORBITER 102 CONFIGURATION

TPS (THERMAL PROTECTION SYSTEM)*	AREA	WEIGHT
	SQUARE FEET	POUNDS
FRSI	3,581	1,173
LRSI	2,741	2,236
HRSI	5,164	9,728
RCC	409	3,742
MISCELLANEOUS	-	2,025
TOTAL	11,895	18,904

*INCLUDES BULK INSULATION, THERMAL BARRIERS, & CLOSEOUTS

THERMAL PROTECTION SYSTEM (TPS)

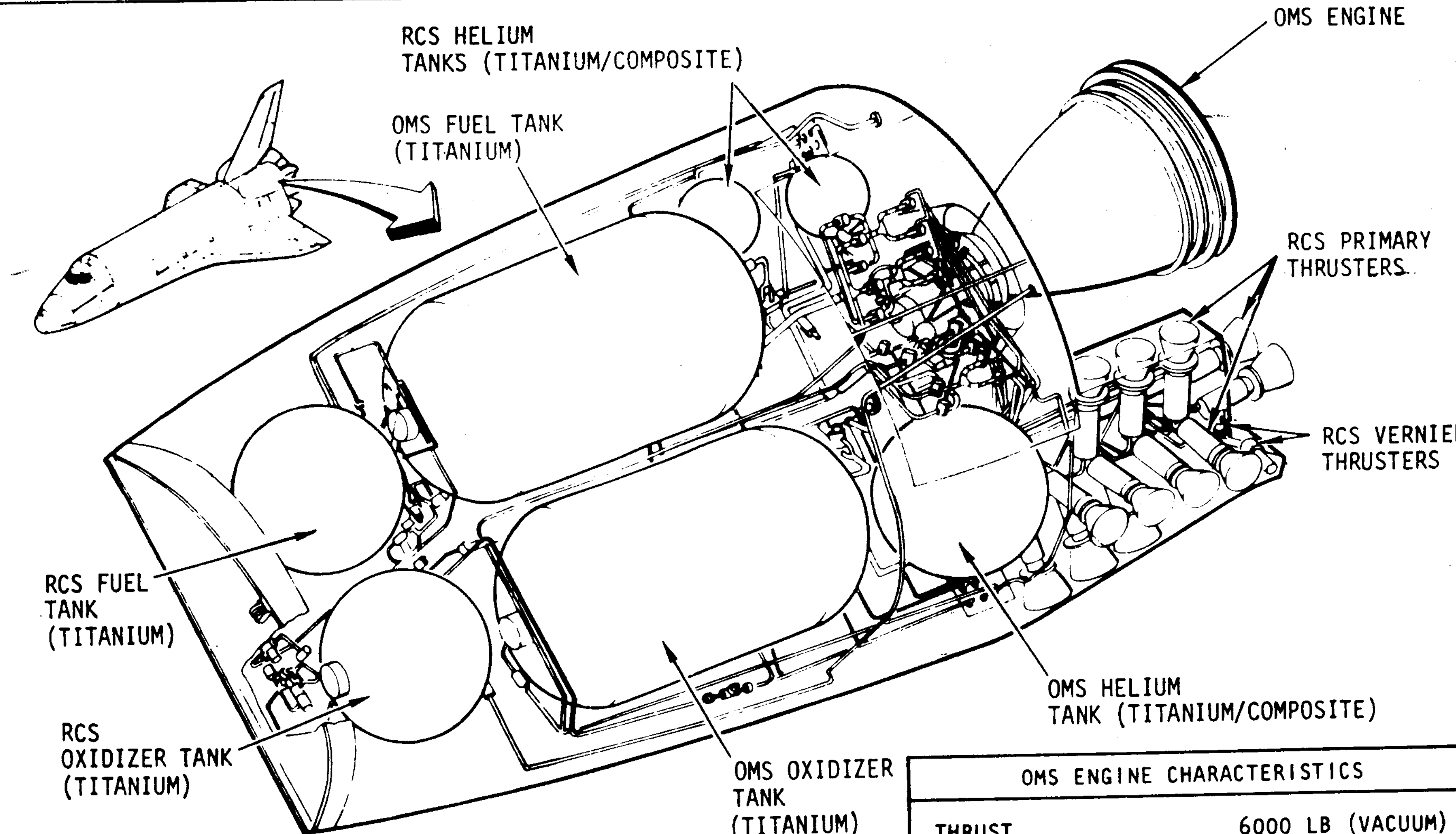
MATERIALS CONFIGURATION



ORBITAL MANEUVER SUBSYSTEM

- GENERAL - 100 MISSION LIFE AND REUSABILITY FOR ALL PROPULSION COMPONENTS
- ENGINE
  PLATELET CONCEPT INJECTOR (EASE OF FABRICATION, HIGH PERFORMANCE).
  ACOUSTIC CAVITY STABILITY CONTROL (BAFFLES NOT USED).
  REGENERATIVELY-COOLED THRUST CHAMBER (USING MMH FUEL).
- COMPOSITE STRUCTURE - 500 LBS. SAVED BY USE OF GRAPHITE-EPOXY
- ACQUISITION SCREENS - USED IN OMS AND RCS TANKS FOR ZERO-GRAVITY EXPULSION OF PROPELLANTS (INSTEAD OF CONVENTIONAL BLADDERS/BELLOWS).

Orbital Mane... Subsystem



OMS ΔV CAPABILITY	1000 FT/SEC (65,000 LB PAYLOAD)
USEABLE OMS PROPELLANT:	23,876 LB TOTAL:
	14,866 LB N_2O_4
	9010 LB MMH

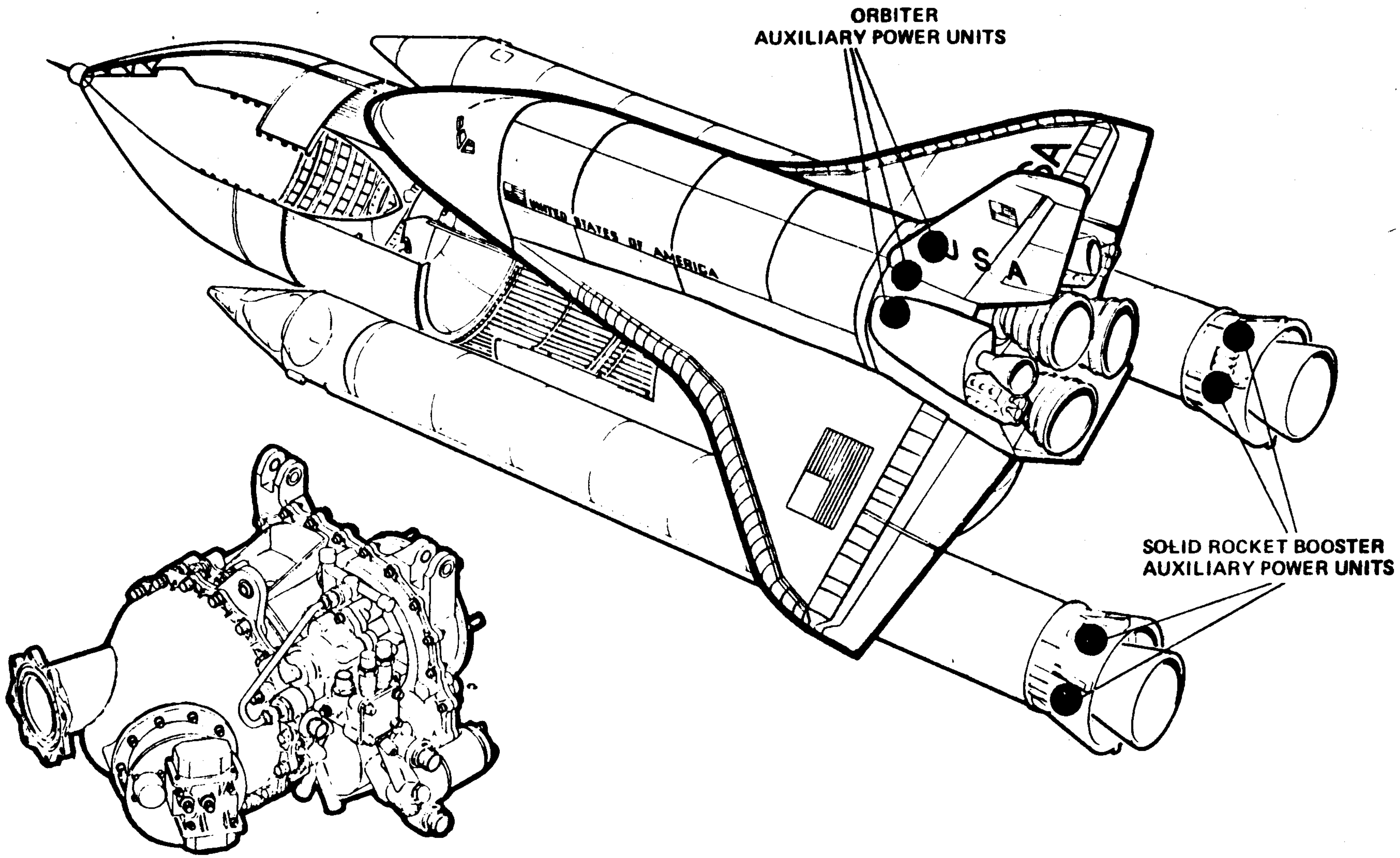
OMS ENGINE CHARACTERISTICS	
THRUST	6000 LB (VACUUM)
SPECIFIC IMPULSE	313.2 SEC
CHAMBER PRESSURE	125 PSIA
MIXTURE RATIO	1.65
GIMBAL CAPABILITY	$\pm 6°$ PITCH $\pm 7°$ YAW

(Contractors: MDAC, St. Louis
AEROJET, California
MARTIN-MARIETTA)

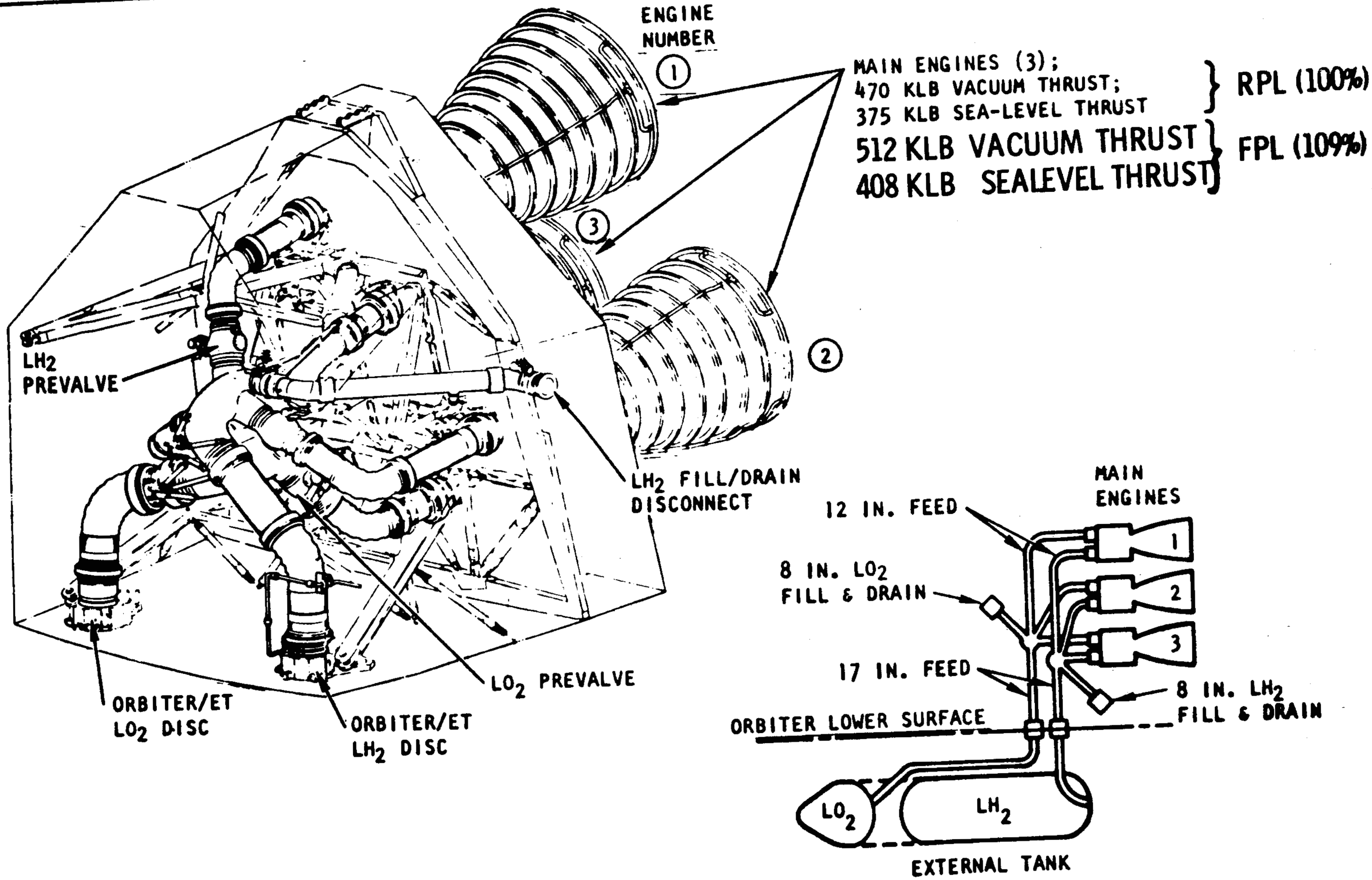
AUXILIARY POWER UNIT (APU)

- FUNCTION - POWERS HYDRAULIC SYSTEM FOR ACTUATING ORBITER AEROSURFACES, ENGINE VALVES, LANDING GEAR AND OTHER SYSTEMS. HIGH-SPEED TURBINE IS DRIVEN WITH HOT GAS FROM DECOMPOSED HYDRAZINE FUEL.
- HIGH POWER IN SMALL PACKAGE (150 HP/92 POUNDS)
- THERMALLY-SUBMERGED CONCEPT (GAS GENERATOR COOLED BY TURBINE EXHAUST GASES)
- HIGH EFFICIENCY FUEL PUMP - HIGH PRESSURE/LOW FLOW WITH LOW-LUBRICITY FLUID (HYDRAZINE)
- LONG LIFE GAS GENERATOR: 20-HOURS (40-HOURS DEMONSTRATED)
- ZERO-GRAVITY LUBRICATION SYSTEM FOR SPEED REDUCTION GEAR BOX

AUXILIARY POWER UNIT SUBSYSTEM



Main Propulsion Subsystem



SPACE SHUTTLE MAIN ENGINE (SSME)

TECHNOLOGY INNOVATION

- LONG LIFE & REUSABILITY

  THE SSME WAS DESIGNED WITH MULTIPLE REUSE AND SEVERAL HOURS OF OPERATION AS BASELINE

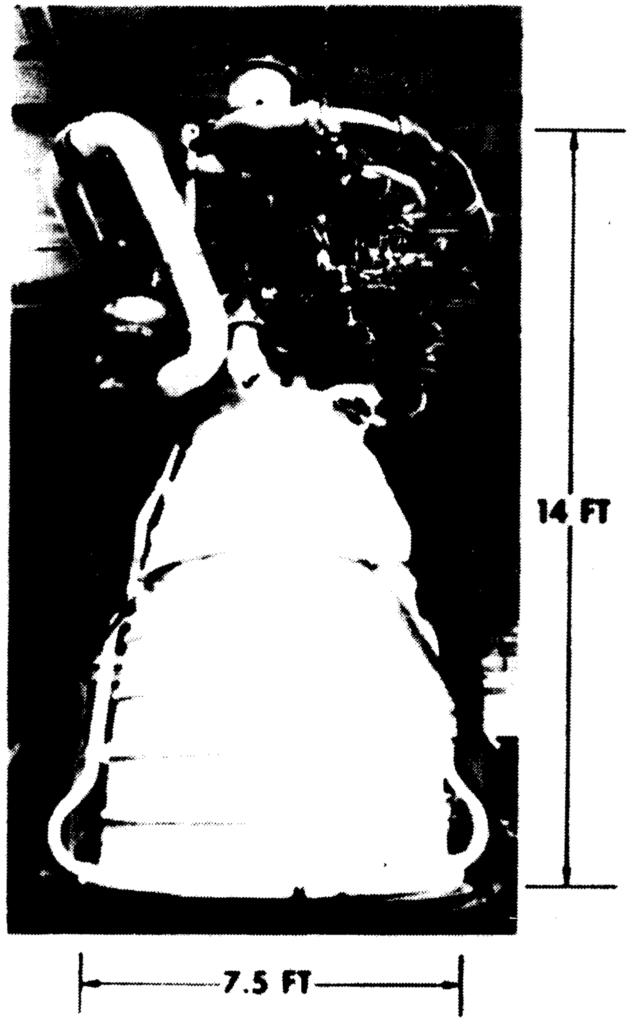
  - DESIGN SPECIFICATION FOR USEFUL LIFE - 7.5 hrs. / 55 STARTS

- THROTTLING

  THE SSME DESIGN ALSO REQUIRES TWO POWER LEVELS OF OPERATION

  - FULL POWER LEVEL (FPL) - 512,000 lbs (109%)
  - RATED POWER LEVEL (RPL) - 470,000 lbs (100%)
  - ENGINE MUST BE THROTTLEABLE FROM 65% - 109% RPL
  - MINIMUM ENVELOPE REQUIREMENT - HIGH P_C DRIVER ALSO
  - MAXIMUM OPERATIONAL FLEXIBILITY REQUIRED

SPACE SHUTTLE MAI_NGINE CHARACTERIST



THRUST	
VACUUM	470K
CHAMBER PRESSURE	2995 PSIA
AREA RATIO	77.5
SPECIFIC IMPULSE (NOM)	
VACUUM	455.2
MIXTURE RATIO	6.0
LIFE	7.5 HRS 55 STARTS
SPECIFICATION DRY WEIGHT	6886 LBS

SPACE SHUTTLE MAIN ENGINE (SSME)

TECHNOLOGY INNOVATION

- CLOSED-CYCLE OPERATION (STAGED COMBUSTION)

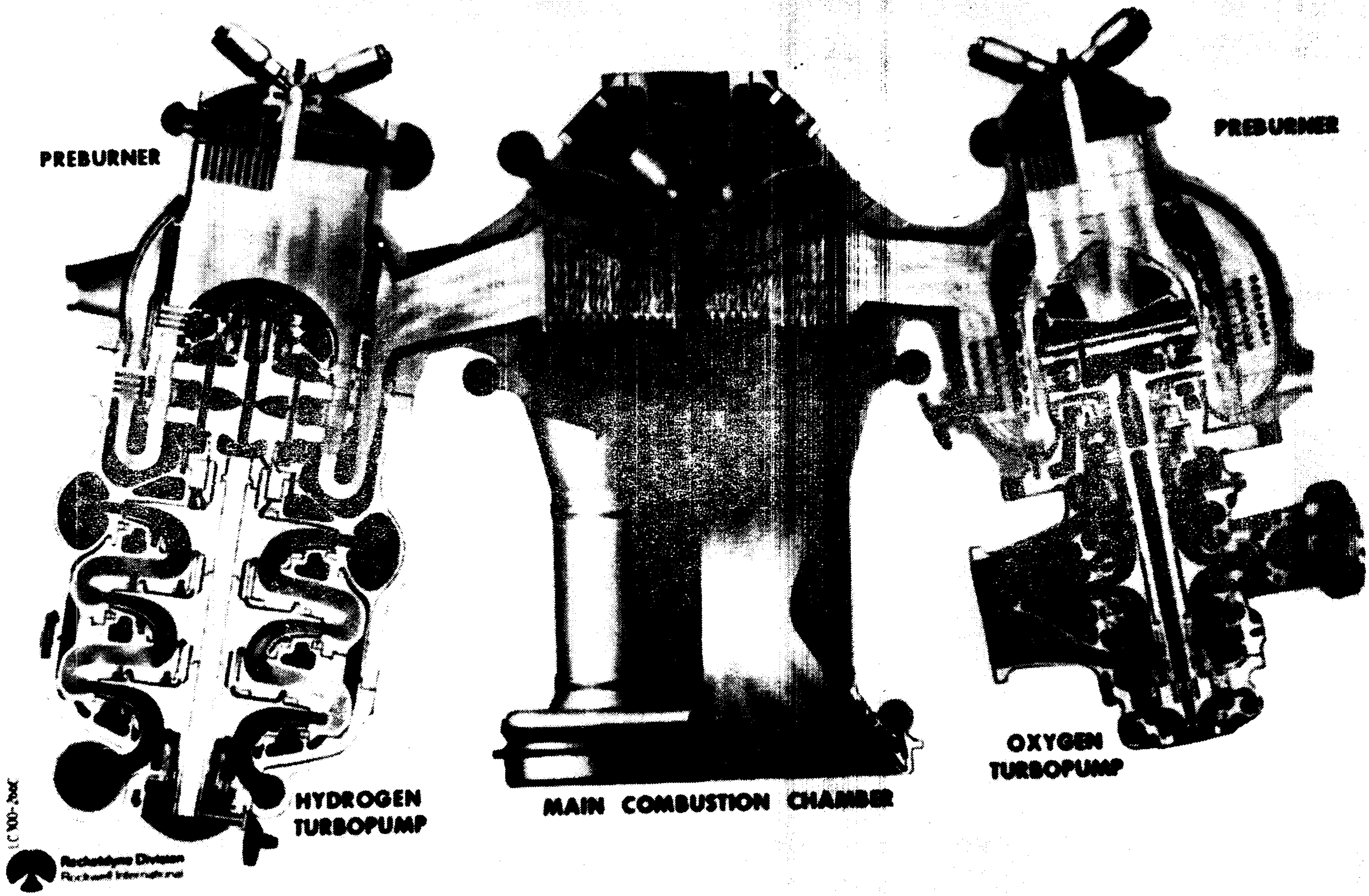
  PREBURNER CONCEPT UTILIZED IN LIEU OF CONVENTIONAL GAS GENERATORS

  - PREBURNER CONCEPT PROVIDES A CLOSED-CYCLE ENGINE TURBO-PUMP DRIVE POWER SOURCE - NO PROPELLANT EXHAUST DUMPED OVERBOARD, THEREFORE HIGHER OVERALL ENGINE SYSTEM EFFICIENCY

  - PREBURNER CONCEPT PROVIDES "TAILORED POWER" SUPPLY TO EACH PROPELLANT LEG OF SSME (LOX & LH_2) PROPELLANT FEED SYSTEMS - EACH PREBURNER IS INDEPENDENT OF THE OTHER ON POWER SETTINGS

  - HIGH CHAMBER PRESSURE (P_C = 3000 psi) PROVIDES FOR EXTREMELY COMPACT ENGINE ENVELOPE, PERMITTING MINIMAL AERODYNAMIC IMPACT ON ORBITER BOATTAIL DESIGN

SSME POWERHEAD ASSEMBLY



SPACE SHUTTLE MAIN ENGINE (SSME)

TECHNOLOGY INNOVATION

- MAIN COMBUSTION CHAMBER

  ELECTROPLATED CLOSE-OUTS/HIGH CONDUCTIVITY MAIN COMBUSTION CHAMBER

  - CONVENTIONAL (PAST DESIGNS) ROCKET ENGINE COMBUSTORS USUALLY EMPLOYED FORMED TUBES OR DRILLED COOLANT PASSAGES

    - HIGHER HEAT FLUX ($\sim$5 - 10x) THAN CONVENTIONAL LOW PRESSURE ENGINES REQUIRES UNIQUE & UNCONVENTIONAL COOLING SCHEME

    - COMBUSTOR LINER FABRICATED FROM COPPER-BASED MATERIAL (NARLOY - Z)

    - SECOND STEP IS NICKEL-PLATING OF CHANNEL CLOSE-OUTS (NASA-FUNDED TECHNOLOGY IN MID - 60's)

MAIN COMBUSTION CHAMBER

GEOMETRY

■NARLOY Z LINER + EDCu BARRIER + EDNi CLOSE-OUT + INCO 718 STRUCTURE SHELL	
■NUMBER OF SLOTS	390
■NUMBER OF ACOUSTIC CAVITIES	30
■INJECTOR END DIAMETER	17.74 IN.
■THROAT AREA	83.41 IN.^{2}
■INJECTOR END TO THROAT LENGTH	14.00 IN.
■CONTRACTION RATIO	2.96:1
■EXPANSION RATIO	5.0:1

OPERATING PARAMETERS (RPL, MR-6.0)

■THROAT STAGNATION PRESSURE	[illegible] PSIA
■COOLANT INLET PRESSURE	[illegible] PSIA
■COOLANT INLET TEMPERATURE	[illegible] R
■COOLANT EXIT PRESSURE	[illegible] PSIA
■COOLANT EXIT TEMPERATURE	477 R
■COOLANT FLOWRATE	[illegible] LB/SEC
■HOT GAS WALL TEMPERATURE AT THROAT	[illegible] F

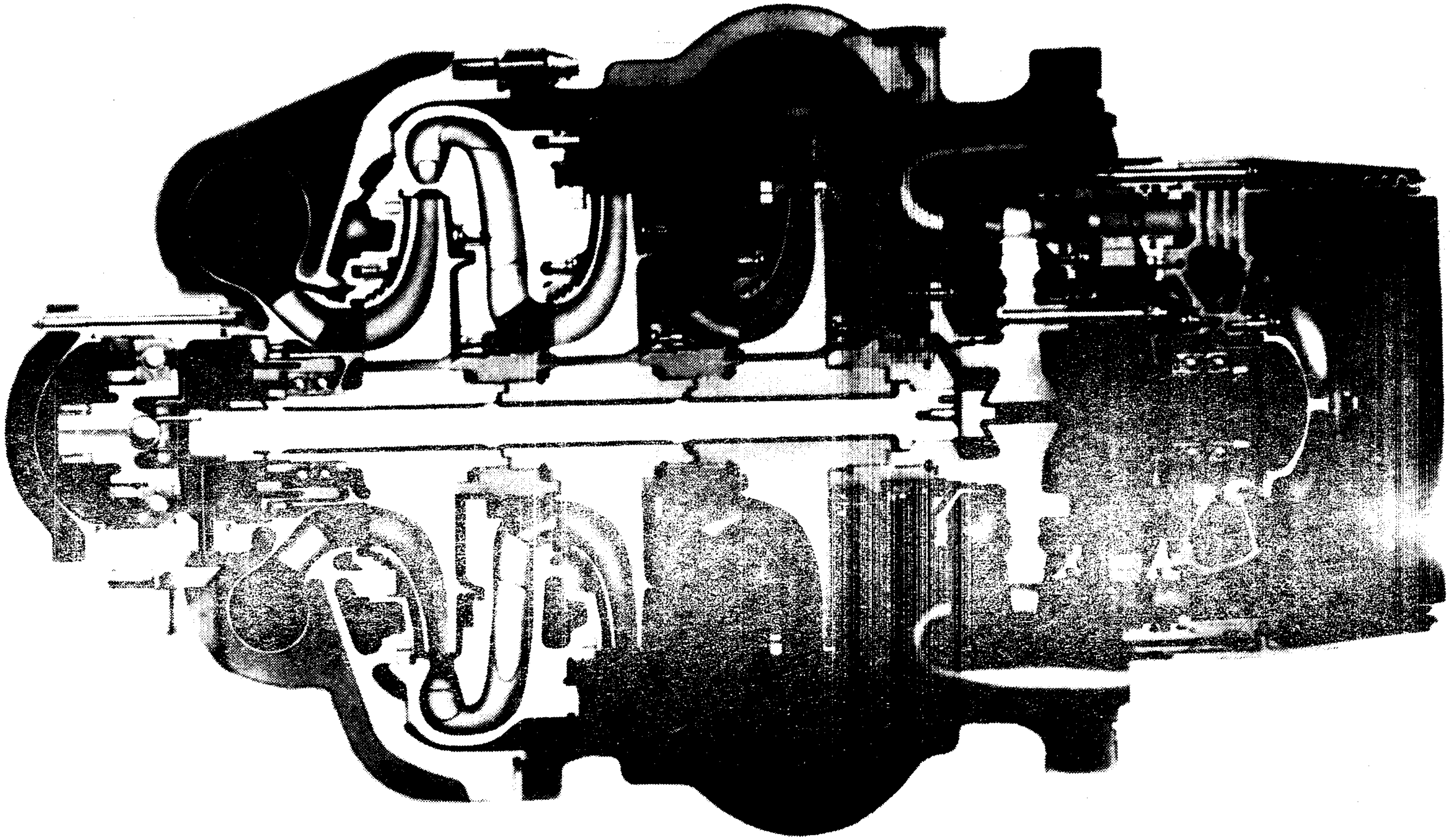
Rockwell International
Rocketdyne Division

SPACE SHUTTLE MAIN ENGINE (SSME)

TECHNOLOGY INNOVATION

- HIGH CHAMBER PRESSURE
  - THE SSME INCORPORATES AN OPERATING CHAMBER PRESSURE (P_C) OF 3000 psig, THREE TO FOUR TIMES THAT OF ANY PREVIOUS OPERATIONAL ROCKET ENGINE
    - HIGH P_c PROVIDES FOR COMPACT DESIGN
    - HIGH P_c PROVIDES FOR HIGH I_{sp} (455 sec)
- HIGH CHAMBER PRESSURE DESIGN NECESSITATES USE OF HIGH TEMPERATURE/HIGH STRENGTH MATERIALS
  - PROPELLANT FEED LINE PRESSURES AS HIGH AS 7500 psig
  - TURBINE HORSEPOWER DENSITY EXTREMELY HIGH: WITH 61,700 TOTAL H.P. AND 700 lbs TOTAL WEIGHT, DENSITY IS ABOUT 88 H.P./lb.
  - NOZZLE/MCC MUST WITHSTAND VERY HIGH PRESSURES

HIGH PRESSUR JEL TURBOPUMP



SPACE SHUTTLE MAIN ENGINE (SSME)

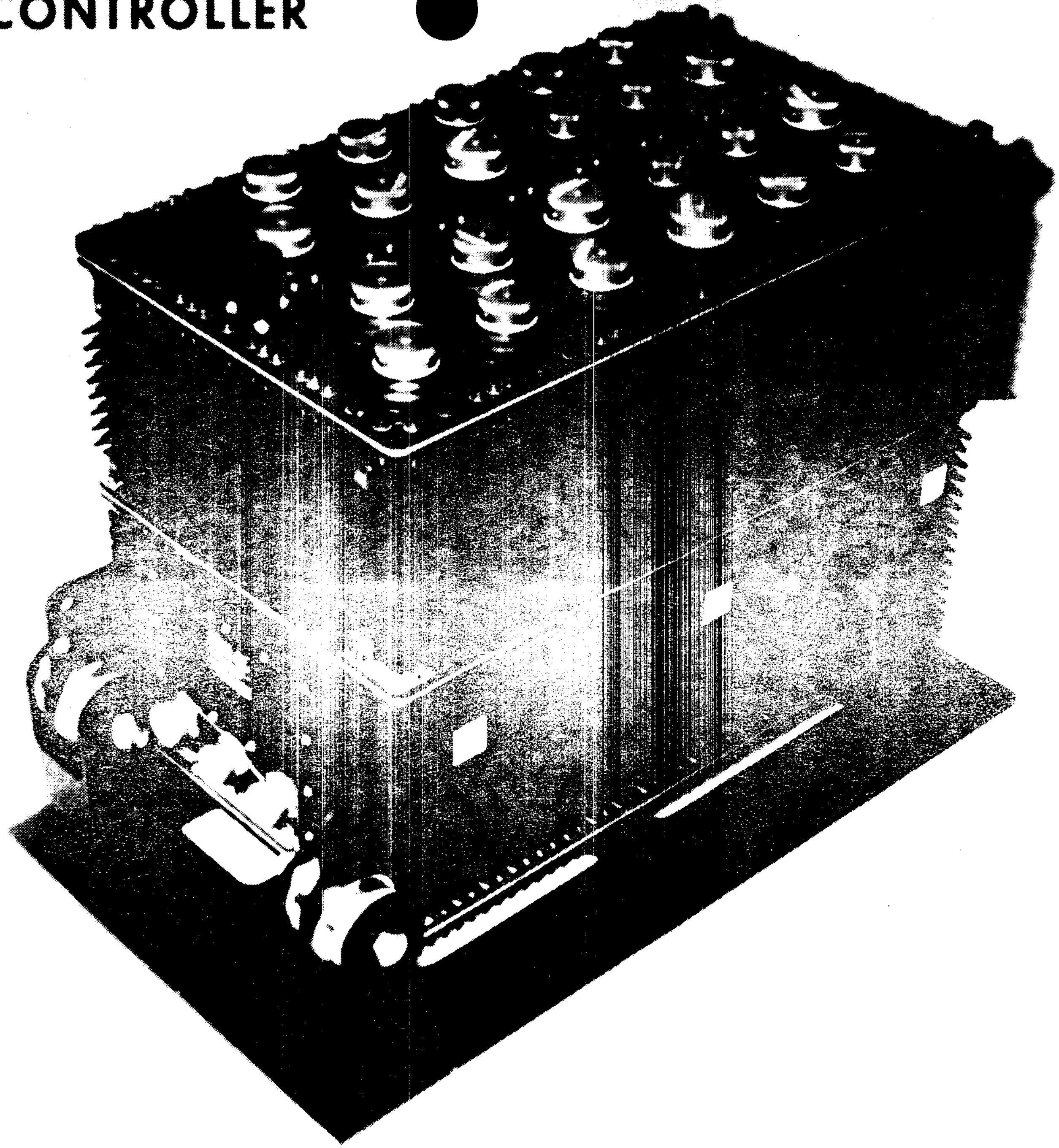
TECHNOLOGY INNOVATION

- COMPUTER CONTROL

  ALL START-UP, SHUT-DOWN, P_C, AND M.R. FUNCTIONS OF THE SSME ARE COMPUTER-CONTROLLED (SOFTWARE)

  - RAPID TURN-AROUND OF TEST VARIABLES MADE POSSIBLE WITH SOFTWARE CHANGES ONLY
  - RELIABLE/REPEATABLE ENGINE CONTROL/MONITORING FROM TEST TO TEST ONLY POSSIBLE VIA COMPUTER-CONTROLLED SYSTEM

SSME CONTROLLER



ADVANCED AVIONICS DESIGN

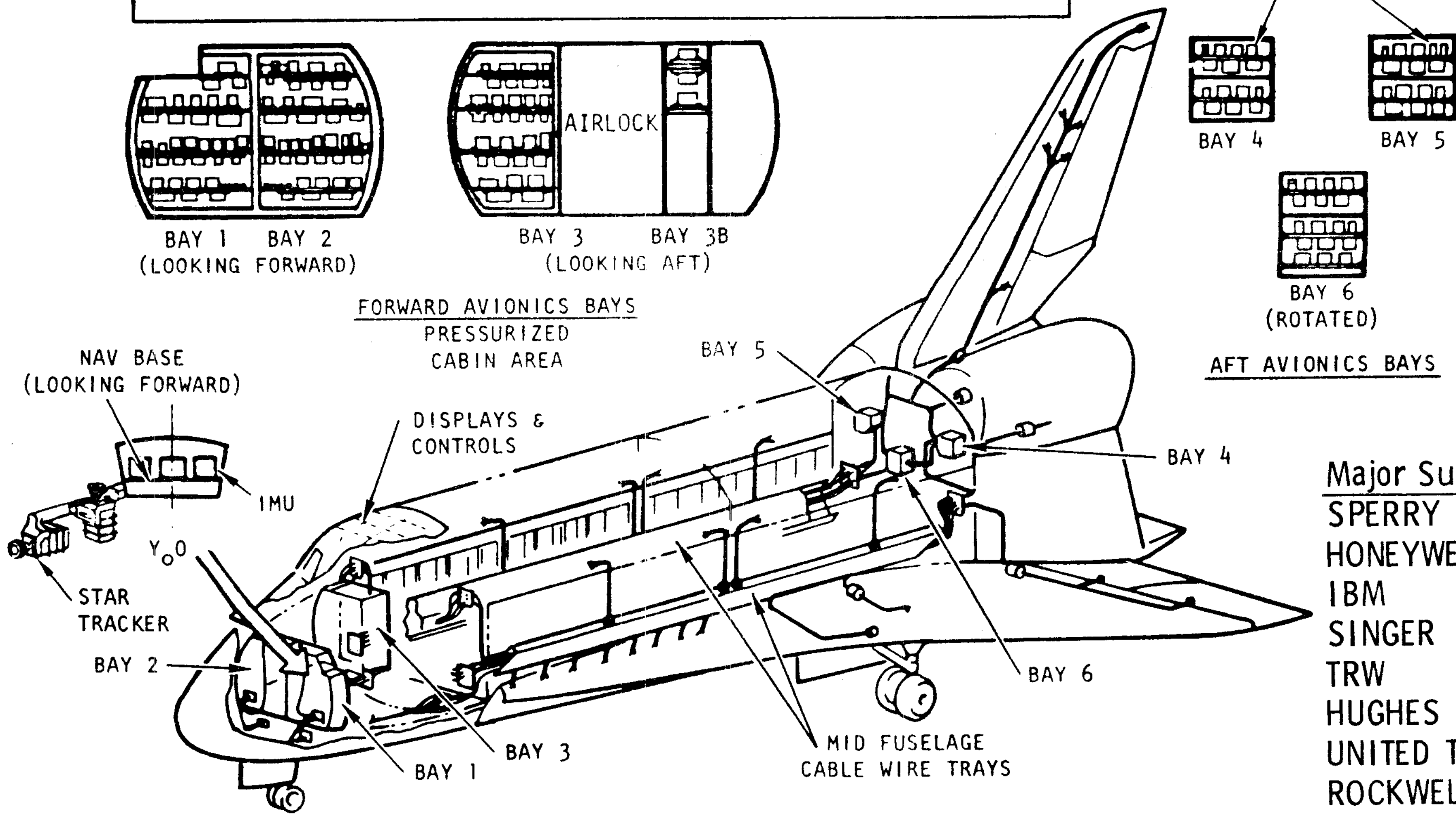
THE SPACE SHUTTLE UTILIZES TWO UNIQUE AVIONICS CONCEPTS:

- DIGITAL FLY-BY-WIRE CONTROL SYSTEM, WHICH
  - INTEGRATES THE DESIGN FEATURES OF AN AIRPLANE AND SPACECRAFT INTO A SINGLE VEHICLE
  - REDUCES THE RISK FOR ANOMALOUS CONDITIONS BY THE USE OF SOPHISTICATED ALGORITHMS
  - IMPROVES THE RESPONSE, STABILITY, AND LOAD RELIEF, RESULTING IN INCREASED PAYLOAD CAPABILITY
- AVIONICS REDUNDANCY MANAGEMENT, UTILIZING NEW AND UNIQUE METHODS WHICH
  - PROVIDE MULTI-COMPUTER REDUNDANCY BY SOFTWARE
  - INCREASE CAPABILITY FOR HARDWARE FAULT DETECTION, ISOLATION, AND SYSTEMS RECONFIGURATION
  - INCREASE SIGNIFICANTLY MISSION SUCCESS PROBABILITY WHILE USING OFF-THE-SHELF AVIONICS EQUIPMENT

Orbiter Avionics Subsystem

AVIONICS SUBSYSTEMS

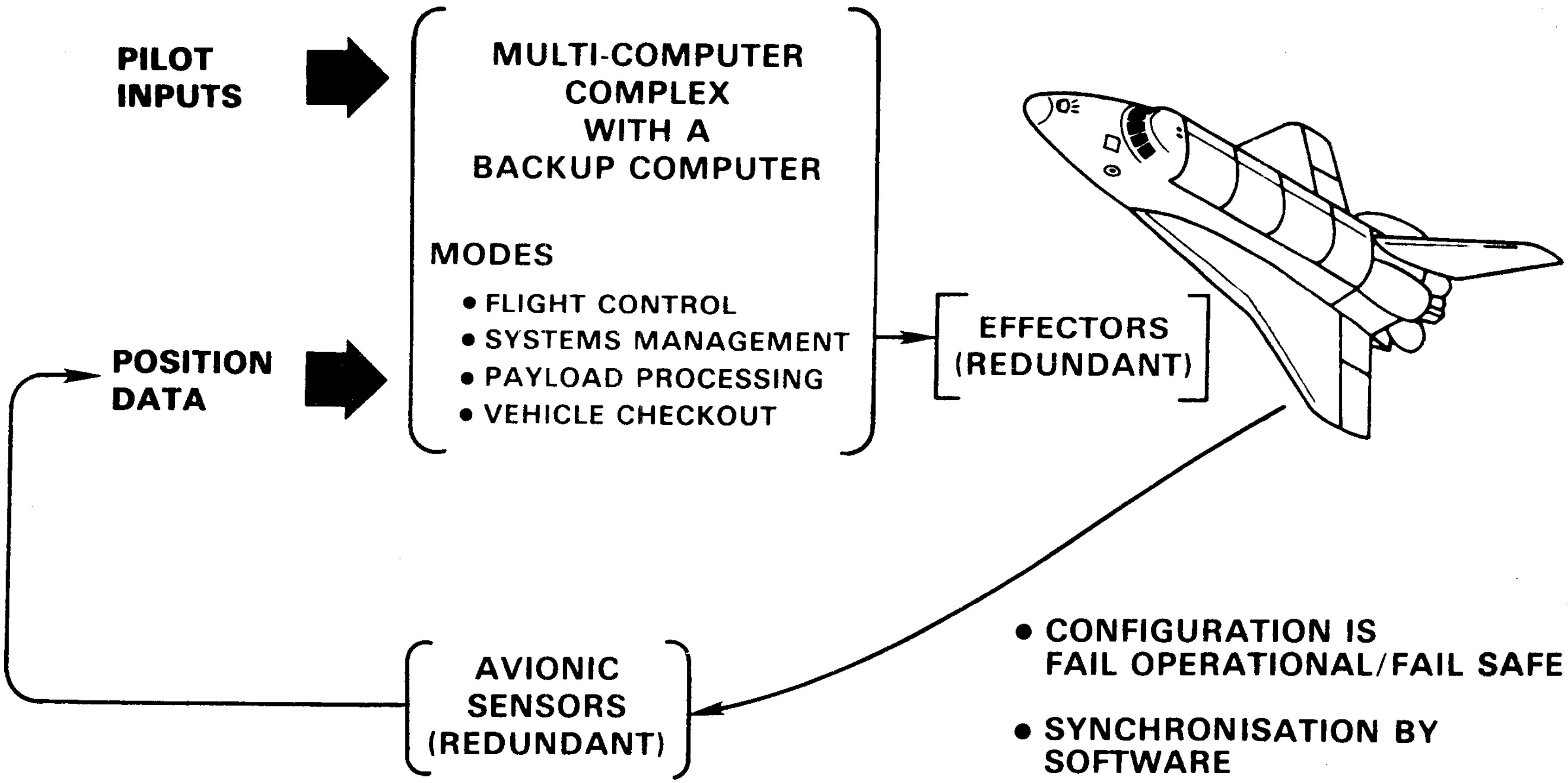
- GUIDANCE & CONTROL
- COMM/TRACKING
- DISPLAYS & CONTROLS
- ELECTRIC POWER DISTRIBUTION
- INSTRUMENTATION
- DATA PROCESSORS



Major Suppliers:

SPERRY
HONEYWELL
IBM
SINGER
TRW
HUGHES
UNITED TECH.
ROCKWELL INT.

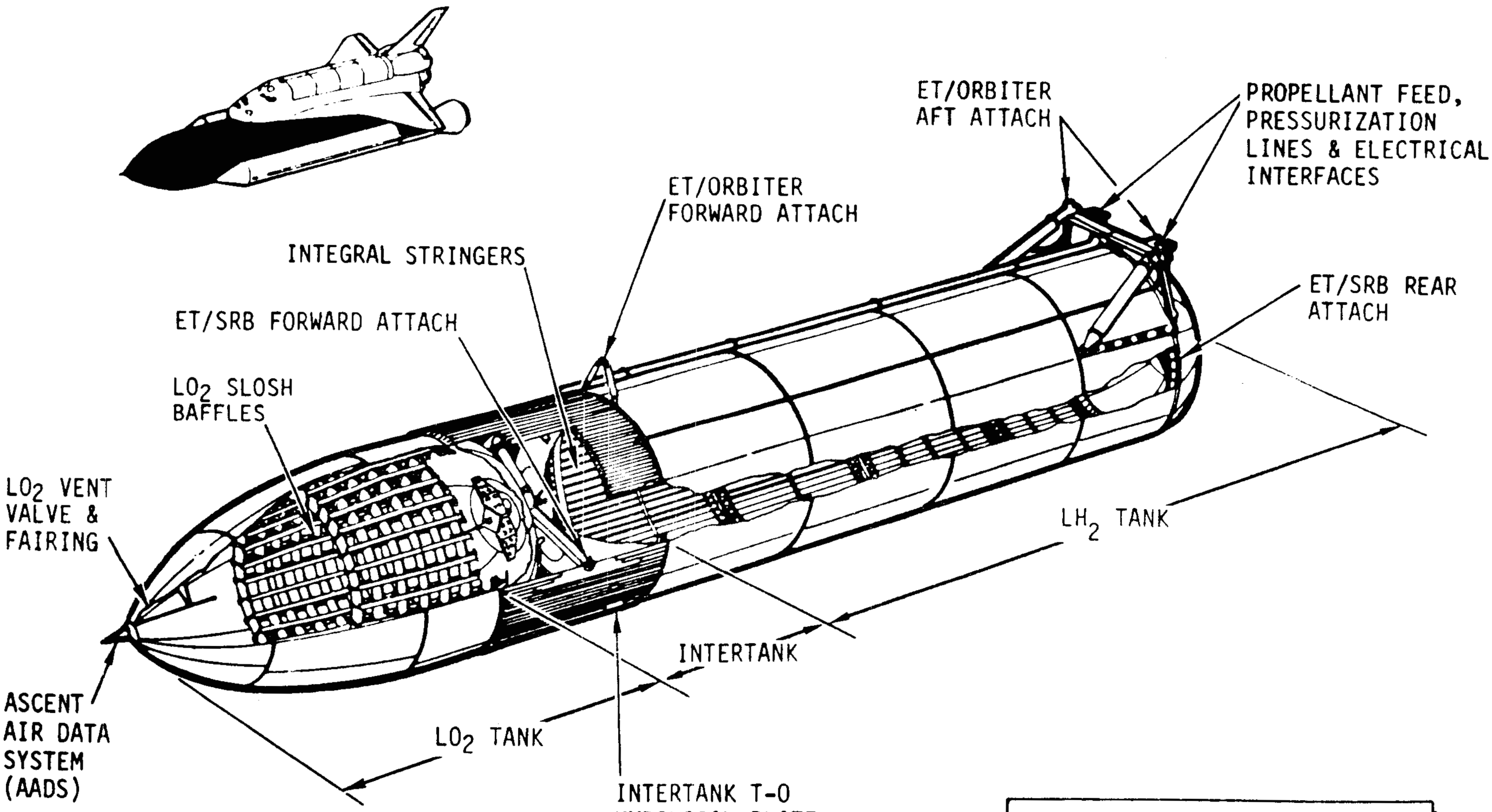
SHUTTLE AVIONICS SYSTEMS



- CONFIGURATION IS FAIL OPERATIONAL/FAIL SAFE
- SYNCHRONISATION BY SOFTWARE
- RECONFIGURABLE FOR EACH MISSION

NASA HQ MT80-4764 (1)
9-4-80

External Tank



DIAMETER = 27 FT 9 IN.
LENGTH = 154.4 FT
PROPELLANT WT = 1.58×10^6 LB
INERT WT = 71,000 LB

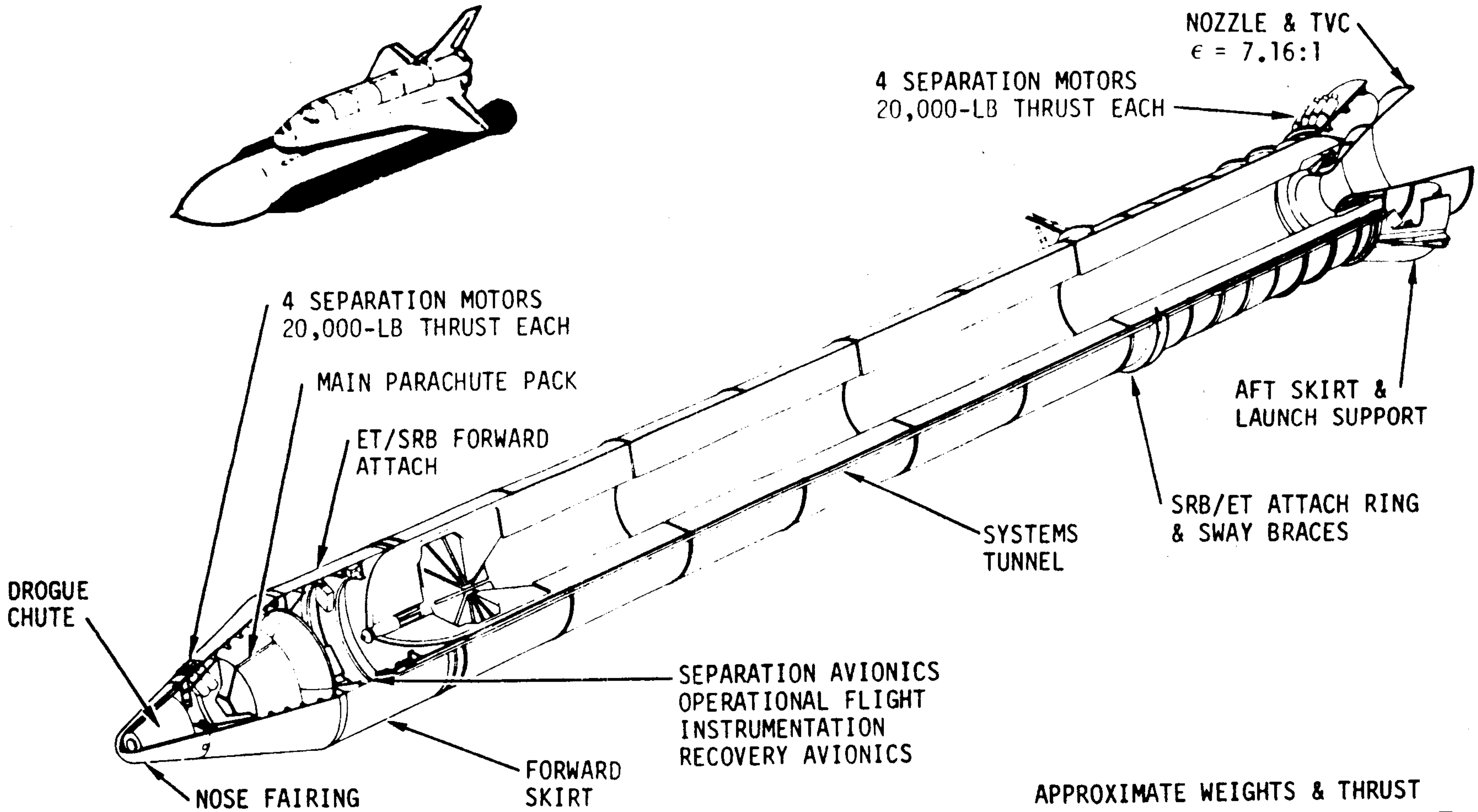
(Contractor: MARTIN-MARIETTA)

SOLID ROCKET BOOSTER

TECHNOLOGY INNOVATION

- REUSABILITY
  - MOTOR CASE CAPABILITY FOR 20 USES
  - STRUCTURES CAPABILITY FOR 40 USES
  - SUBSYSTEMS CAPABILITY FOR 20 USES
    - TVC SYSTEM
    - E&I SYSTEM
  - PARACHUTES CAPABILITY FOR 10 USES
- LARGEST SIZE OPERATIONAL PARACHUTES
  - 115 ft. DIAMETER
  - REDUCTION IN SPLASHDOWN VELOCITY TO 85 ft/sec
    - SRB SPLASHDOWN WEIGHT $\approx$ 164,000 lbs.

Solid Rock Booster



DIMENSIONS

LENGTH . . . 1790 IN.
DIAMETER . . 146 IN.

APPROXIMATE WEIGHTS & THRUST

GROSS WEIGHT . . .	1,293,500 LB
INERT WT	184,600 LB
THRUST (SL)	2.65M LB

(Contractor: THIOKOL, Utah)

LAUNCH PROCESSING, CHECKOUT AND CONTROL

AN AUTOMATED LAUNCH PROCESSING SYSTEM HAS BEEN DEVELOPED AND IS IN USE AT KSC WHICH ALLOWS SIMULTANEOUS CHECKOUT, OPERATION, AND PROCESS CONTROL OF A VARIETY OF FLIGHT VEHICLE AND GROUND FACILITY SUPPORT SYSTEMS. ALTHOUGH THIS SYSTEM MAKES USE OF STANDARD COMPUTER AND PERIPHERAL HARDWARE, ADVANCES IN THE STATE-OF-THE-ART ARE BEING MADE IN:

- MINI-COMPUTER NETWORKING FOR REAL-TIME COMMAND AND CONTROL BY USING A COMMON DATA SOURCE

- DEVELOPMENT AND UTILIZATION OF AN AUTOMATED CHECKOUT AND PROCESS CONTROL LANGUAGE TO PROGRAM THE SYSTEM